GEOMAR REPORT

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Helmholtz-Zentrum für Ozeanforschung Kiel

RV ALKOR Fahrtbericht / Cruise Report AL533

Mutual Field Trials of the Manned Submersible JAGO and the Hover-AUVs ANTON and LUISE off the Aeolian Islands, Mediterranean Sea

Catania (Italy) – La Seyne-sur-mer (France)
05.02. – 18.02.2020

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Das GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel
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1 Cruise Summary

1.1 Summary in English

The tight program of scientific research cruises usually does not leave enough time for thorough tests of new research equipment and their system components, nor for extensive pilot and handling training. For this reason, ship time was requested for sea trials of two types of autonomous (not tethered) underwater vehicles owned by GEOMAR, the manned 400-meter submersible JAGO and the Hover-AUVs ANTON and LUISE, type Girona500. The aim was to test several technical and operational aspects with both vehicles at locations with differently structured terrain (from flat ground to steep rocky slopes) and to water depths of up to 500 meters. The Aeolian Islands in the Tyrrhenian Sea north of Sicily were chosen as test area. The volcanic islands offer sheltered sea conditions at their leeway, and bottom currents are usually weak or absent. Rocky and steep slopes are located in short distances to areas with flat underwater topography, providing ideal test conditions.
Dives took place from 07-15 Febuary in the Baia di Levante between Punta Roja and Punta Luccia of Vulcano island (38°24.70’N, 14°58.56’E), off the east coast of Lipari Island (38°26.45’N, 14°58.12’E and 38°30.05’N, 14°58.10’E), off Panarea island (38°38.62’N, 15°05.18’E and 38°37.43’N, 15°04.61’E) and off the Sciara del Fuoco, the northwest slope of the active Stromboli volcano (38°48.19’N, 15°12.15’E). Seven dives were performed with the manned submersible JAGO to train piloting, sampling and video-recording in steep terrain, to establish transfer of USBL positioning data between the vessel and the submersible via modem, to test rim thruster performance, and rescue buoy release. The dives were performed at bottom depths between 50 and 310 meter. The Hover-AUVs ANTON and LUISE were deployed in total 11 times for 22 missions in water depth between 15-200 meter. Dives were used to test the BELUGA network system for data exchange between different underwater vehicles and the new camera system CoraMo for photographic surveys. At the last station on February 15, a simultaneous dive of JAGO and AUV ANTON were performed during which both vehicles made images of one another and were tracked simultaneously via USBL and BELUGA. Only one out of nine days in the working area was lost for deployments due to strong winds. The vessel docked in La Seyne-sur-mer / France on February 17, 2020.
The cruise was also used to gather material for public outreach work of GEOMAR. A cameraman and a photographer documented all aspects of the work on board with still and 2D-video cameras, with a 360°-camera for VR-viewing and 3D-projection and a drone for aerial photography. Images of the sea floor and rock samples will be analysed by the Italian volcanologist Dr. Daniele Casalbore of the University Sapienza in Rome who joined the cruise.

1.2 Zusammenfassung

Das enge Programm wissenschaftlicher Forschungsfahrten lässt in der Regel nicht genügend Zeit für gründliche Tests neuer Forschungsgeräte und ihrer Systemkomponenten. Dies gilt auch für ein umfangreiches Piloten- und Handling-Training. Aus diesem Grund wurde für zwei nicht kabelgebundene Unterwasserfahrzeuge des GEOMAR, das bemannte Tauchboot JAGO und die Hover-AUVs ANTON und LUISE, Typ Girona500, Schiffszeit beantragt und bewilligt, die ausschließlich für Gerätetests und ein intensives Trainingsprogramm genutzt wurde, und zwar

unter Bedingungen, die mit Forschungsausfahrten vergleichbar sind. Ziel war es, verschiedene technische und operative Aspekte beider Fahrzeuge in unterschiedlich strukturiertem Gelände (von flachem Boden bis zu steilen felsigen Hängen) und in Wassertiefen von bis zu 500 Metern zu testen. Als Testgebiet wurden die Äolischen Inseln im Tyrrhenischen Meer nördlich von Sizilien ausgewählt. Die Vulkaninseln bieten auf ihrer Leeseite windgeschützte Seebedingungen und unter Wasser sind Grundströmungen schwach ausgeprägt. Felsige und steile Hänge liegen in kurzer Entfernung zu Gebieten mit flacher Unterwassertopographie. All dies sind ideale Testbedingungen.

Die Tauchgänge fanden vom 07. bis 15. Februar in der Baia di Levante zwischen Punta Roja und Punta Luccia vor der Insel Vulcano (38°24.70'N, 14°58.56'E), vor der Süd- und Ostküste der Insel Lipari (38°26.45'N, 14°58.12'E und 38°30.05'N, 14°58.10'E), vor der Insel Panarea (38°38.62'N, 15°05.18'E und 38°37.43'N, 15°04.61'E) und an der Sciara del Fuoco, dem Nordwesthang des aktiven Vulkans Stromboli (38°48.19'N, 15°12.15'E) statt. Sieben Tauchgänge wurden mit dem bemannten Tauchboot JAGO durchgeführt. Beim Piloten-Training wurde u.a. Probenahme und Videoaufzeichnung in steilem Gelände trainieren. Während der Tauchgänge wurde außerdem die Übertragung von USBL-Positionsdaten zwischen Schiff und Tauchboot über ein Modem etabliert, die Leistung neuer Ringantriebe überprüft und das Auslösen der Rettungsboje unter Seebedingungen getestet. Die Tauchgänge fanden in Tiefen zwischen 50 und 310 Metern statt. Die Hover-AUVs ANTON und LUISE wurden insgesamt elf Mal für 22 unterschiedliche Test-Missionen in Wassertiefen zwischen 15 und 200 Metern eingesetzt. Bei den Tauchgängen wurde das neue BELUGA-Netzwerk zur Kommunikation und zum Datenaustausch zwischen mehreren Unterwasserfahrzeugen getestet sowie das neue Kamerasystem CoraMo für fotografische Surveys. An der letzten Station am 15. Februar wurde ein gemeinsamer Tauchgang von JAGO und AUV ANTON durchgeführt, bei dem beide Fahrzeuge unter Wasser Fotos und Videos voneinander machten und gleichzeitig über USBL und BELUGA von Bord der ALKOR verfolgt wurden. Nur einer von insgesamt neun Tagen Arbeitszeit vor Ort ging aufgrund starker Winde für Geräte-Einsätze verloren. Das Schiff legte am 17. Februar 2020 in La Seyne-sur-mer / Frankreich an.

Die Ausfahrt AL533 wurde auch genutzt, um Material für die Öffentlichkeitsarbeit des GEOMAR zu sammeln. Ein Kameramann und ein Fotograf dokumentierten alle Aspekte der Arbeit an Bord mit Foto- und 2D-Videokameras, einer 360°-Kamera für Virtual-Reality-Projekte und 3D-Projektion sowie einer Drohne für Luftaufnahmen. Die Videoaufnahmen des Meeresbodens und die während der JAGO-Tauchgänge gesammelten Gesteinsproben werden von dem italienischen Vulkanologen Dr. Daniele Casalbore von der Universität Sapienza in Rom analysiert, der ebenfalls an der Ausfahrt teilnahm.

2 Participants

2.1 Scientific Party

Name	Discipline	Institution
Hissmann, Karen	Submersible JAGO / Chief Scientist	GEOMAR
Schauer, Jürgen	Pilot Submersible JAGO	GEOMAR
Striewski, Peter	Pilot Submersible JAGO	GEOMAR
Weiß, Tim	Software Engineer DSM	GEOMAR
Wenzlaff, Emanuel	AUV-Team	GEOMAR
Leibold, Patrick	AUV-Team	GEOMAR
Diller, Nikolaj	AUV-Team	GEOMAR
Reißmann, Sylvia	AUV-Team	GEOMAR
Hampe, Hendrik	Video-Technician	GEOMAR
Klimmeck, Jens	Cameraman 360° Imaging	GEOMAR
Linke, Nikolas	Photo- + Video-Documentation	GEOMAR
Casalbore, Daniele	Scientist volcanology	USR

2.2 Participating Institutions

GEOMAR	Helmholtz-Zentrum für Ozeanforschung Kiel
USR	University Sapienza of Rome, Dept. Earth Science

3 Research Program

3.1 Aims and Agenda of the cruise

The aim of the AL533-cruise "JAGO-AUV-FieldTrials" was to perform mutual sea trials of two untethered underwater research vehicles, the manned submersible JAGO and the Hover-AUVs ANTON and LUISE (Type Girona500) in differently structured terrain at water depths of up to 500 meter. The tight program of science-focused research cruises usually does not leave enough time for in-depth pilot and handling training and for testing of new technology. We therefore applied ship time exclusively for those purposes. The sea trials should be performed under conditions that are representative for typical research applications.

The GEOMAR-owned manned research submersible JAGO (see Figure 5.1.1.1), which carries two people to maximum water depths of 400 m, is in operation since 30 years and has performed more than 1400 dives. It is maintained and operated by a small team of three: two technicians / pilots, and one scientific and operational coordinator (top-side dive supervisor). The long-time chief pilot and technician, who joined all JAGO missions since the commissioning of the submersible in 1989, is going to retire in the course of 2020. The pilot/technician who was appointed to take over the chief pilot/technician position needed more sophisticated training dives in complex and highly structured terrain, which cannot be found e.g. in the Baltic Sea close to GEOMAR. Furthermore, the submersible recently underwent some technical changes. Renewals comprised, among others, the integration of computer-controlled rim thrusters and acoustic data transfer and communication via USBL. All renewals needed to be tested and – if necessary adjusted – under conditions that are typical for research cruises. They also needed to be tested in larger water depths than those that can be reached in submarine habitats in the Baltic Sea.

The new hover capable Autonomous Underwater Vehicles (AUV) Type Girona500 – named ANTON and LUISE – were bought by GEOMAR in 2018. They have a compact size of 1x1x1,5 m each (see Figure 5.2.1.1) and a total weight of up to 200 kg that includes all necessary electronics and thrusters. The AUVs are capable of diving down to 500 m and have a battery capacity for missions of up to 8 hours duration. The vehicles are equipped with various systems that all together enable the precise calculation of their current position and allow real time navigation (INS, DVL, GPS and USBL). The acoustic modems of the USBL system can also be used to exchange basic information and simple commands between the surface control station and the AUVs. The AUV-Team is presently developing a new navigation and communication software network, named BELUGA, that enables (1) the monitoring of the movements of several vehicles underwater and (2) the exchange of messages and commands between individual vehicles and the ship, between several moving units themselves, and between vehicles and acoustic transponders that are temporary moored on the seafloor. AL533 was used to test the new BELUGA system in-depth at sea.

Due to their modular design and a payload of 35 liters of volume, the AUVs can be equipped with additional instruments for specialized tasks, e.g. a multibeam sonar for mapping or cameras for photographic surveys. The AUV-Team recently developed a new camera system, named CoraMo MK2 that needed to be tested for the first time under marine and deep-water conditions.

The AUV-team is still in the process of getting to know the vehicles, their possibilities and their limits. All experiences especially gathered during sea trials and off-shore cruises are therefore extremely helpful to improve this new technology for its future scientific use.

In summary, the major cruise objectives were:

- Training of all aspects of operating and piloting the manned submersible JAGO from on board a research vessel under sea conditions similar to research cruises, including sampling with the manipulator arm and video mapping of heterogeneous terrain (low relief seafloor vs. high relief sites)
- Testing of the submersible's new side thrusters (computer-controlled rim thrusters)
- Establishing acoustic data transfer and communication via USBL modem between the control station on board the vessel and the submersible, mainly for improving underwater navigation and orientation
- Testing of the submersible's emergency buoy release and rescue procedures
- Establishing an USBL network with several modems in use
- Testing and deployment training of novel shallow water Hover-AUVs as platforms for optical imaging (CoraMo MK2 camera system) and new underwater communication software (BELUGA software).
- Testing next-generation marine research survey technology in the form of multiple communicating platforms (e.g. submersible, AUVs, moored transponders) to provide continuous and accurate underwater navigation as well as rapid feedback of sensor data
- Collecting high-quality photo-, video- and 360°-images for various purposes of media and public outreach work at GEOMAR

3.2 Work area of the cruise

The selection of the region in which the cruise finally should take place was handled very flexible in the proposal for ship time since the final route of the vessel was not defined at that time. The main requirements for a suitable test area were: (1) structured submarine terrain at water depths of up to 500 meters and (2) calm sea conditions that allow vehicle deployments independently from weather conditions. Those conditions are for example usually found at the lee side of high oceanic islands. The volcanic Aeolian Islands in the Tyrrhenian Sea north of Sicily / Italy were finally selected as work area for AL533 (Figure 3.2.1) because they were close to the work area of the previous ALKOR cruise (AL532). AL532 took place off the east coast of Sicily and Catania was therefore the port of the cruise start of AL533. The Aeolian islands offer sheltered sea conditions at their leeway, and bottom currents are usually weak or absent. Rocky and steep slopes are located in short distances to areas with flat underwater topography, which provided ideal test conditions.

Suggestion for suitable dive sites around the Archipelago were provided by colleagues of the University Sapienza in Rome who work since many years on the geology and volcanology of the Aeolian islands (Romagnoli et al. 2013, Casalbore et al. 2010). The islands that were finally selected for coastal dives were Vulcano, Lipari, Panarea and Stromboli. The sheltered bay between Punta Roja and Punta Luccia in the Baia di Levante in the north-eastern sector of Vulcano island was one dive site (38°24.70'N, 14°58.56'E). The Baia di Levante is a broken caldera ring (La Fossa caldera rim) that is open to the east where it runs out into a deep gulf. Gently sloping seafloor is found in close vicinity to steep slopes and almost vertical cliffs, the remains of the caldera rim. The bay is well sheltered against the prevailing west wind by the Fossa cone (391 m max. height) which is the dominant elevation on the volcanic island. A field of well-distinguished pillow lava mounds of up to 70 m height each off the southeast coast of Lipari Island (38°26.45'N, 14°58.12'E) provided a good test area for precise JAGO navigation and maneuvering in rugged terrain. The east coast of Lipari island offers several other interesting areas for test dives combined with some exploration options (e.g. 38°30.05'N, 14°58.10'E). The submarine platform around Panarea island has a shallow topography and the seabed is mainly covered with soft sediment. An area east of the island is called the "Panarea vent site", a field of volcanic gas seeps located between 10 and 80 m water depth (Schmidt et al. 2015). One of the venting sites was chosen for testing a horizontal multibeam echo sounder attached to JAGO (38°38.62'N, 15°05.18'E). The shallow topography was also ideal for AUV dives and a mutual dive of both the submersible and AUV ANTON (38°37.43'N, 15°04.61'E). The Sciara del Fuoco, the northwest slope of the active Stromboli volcano (38°48.19'N, 15°12.15'E) was of special interest of the Italian colleague. Here, a long video and sampling transect with the submersible was performed along the 100 m contour line.

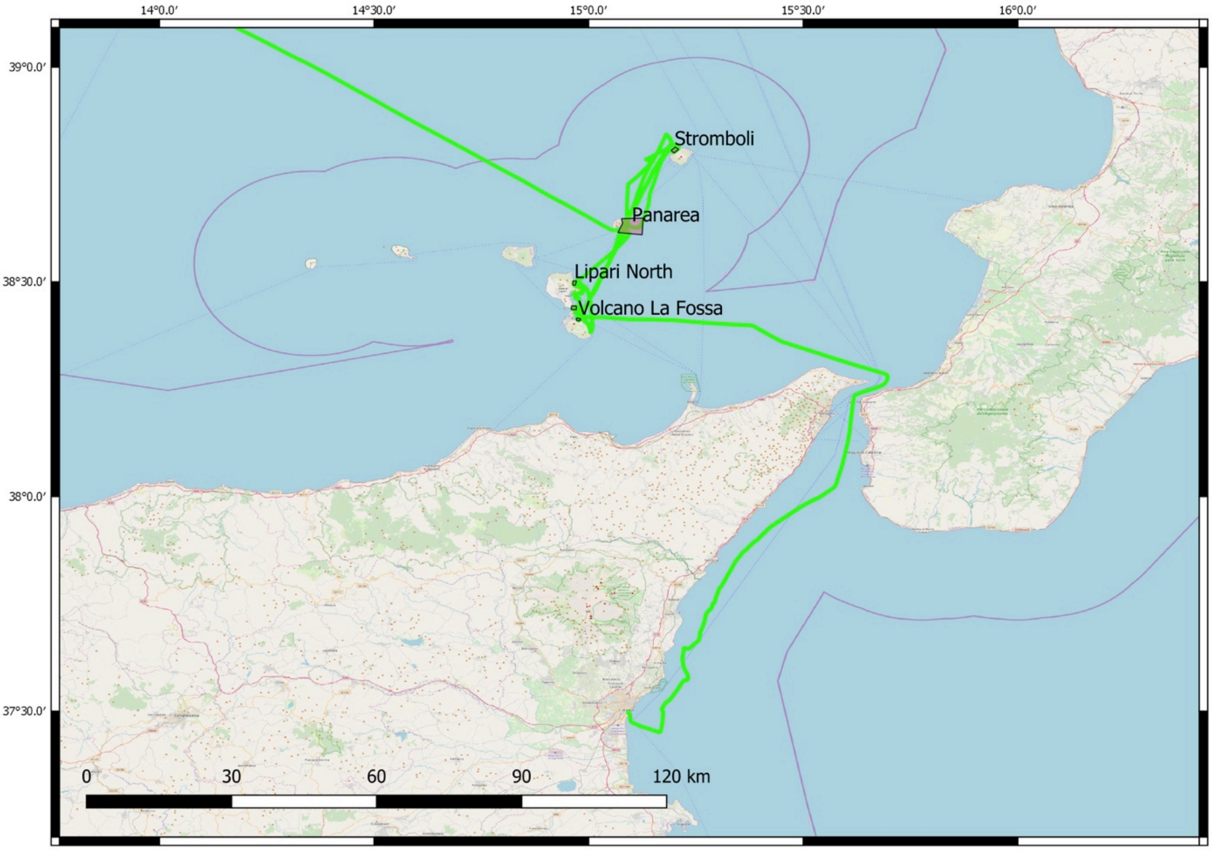

Fig. 3.2.1 Track chart of R/V ALKOR Cruise AL533.

4 Narrative of the Cruise

The submersible container and the Hover-AUVs, which were transported to Catania by truck, were delivered to the berth of FS ALKOR in Catania port on **03 February**. A port crane transferred the submersible, its transport container, and the AUVs on board of ALKOR in the afternoon. The submersible container was lashed down on the aft deck, the submersible on the starboard deck next to the opening of the ship's side, and the AUVs in the hangar. The dry lab was chosen as control lab for both the submersible and the AUV operation. The cruise participants started with installing the support equipment immediately after the equipment was loaded on board the vessel.

04–05 February. All participants of AL533 including the Italian guest scientist officially embarked the vessel in the morning of February 04. In a meeting between the Captain and the Cruise leader it was decided to postpone the departure of the vessel by two days to avoid the forecasted strong wind and high swell in the Strait of Messina and the Tyrrhenian Sea north of Sicily. The forecasted sea conditions would have made it difficult to pass the Strait and the area north of it during transit to the Aeolian Islands. The additional two days in port were used for further preparations of the submersible and the AUVs and the installation of their support equipment (USBL in the moon pool etc). The multibeam maps of the work areas, which were provided by the Italian colleague, were calibrated for their integration into the navigation software. In a meeting, all participants of the cruise including the Captain and the crew were informed in detail about the aim to capture comprehensive material for public outreach purposes (photographs, videos, aerial shots by drone and 360°-video). Afterwards all participants signed a declaration of consent for the use of personal images and personal data.

06 February. FS ALKOR left the port of Catania early in the morning at 06:18. The transit towards the Tyrrhenian Sea was performed in slow speed due to the still unfavorable conditions north of the Strait of Messina. They improved only slowly during the day. The chief mate provided comprehensive safety instructions to all cruise participants, and afterwards the teams continued with their technical preparations.

07 February. The Strait of Messina was passed at 05:00. During the morning, the crew was introduced to the steps of the launch and recovery procedure the submersible. The deck crew prepared the work boat and the necessary lines for the first deployment. The vessel arrived at the first work area, the Baia de Levante off **Vulcano**, at 10:40. At first, the Captain and the Cruise leader watched the fast ferries passing by to get a general idea of the local traffic. The highly frequented ferry route runs close to the selected dive sites. After lunch, the handling trials with JAGO took place (deployment and recovery of the submersible with the modified / shortened main deck crane). In the afternoon, AUV LUISE was deployed for a trim test and a first acoustic communication test with the EvoLogics transponder. The transponder was lowered only few meters into the water and stayed attached to the telescopic crane on the starboard aft. Communication tests were also performed with the USBL modem that was going to be attached to JAGO for tracking the submersible under water. The USBL data were implemented into the navigation software OFOP and the BELUGA system.

08 February. After breakfast, the first JAGO dive (#1426-1) with Peter Striewski as pilot and Nikolaj Diller as observer was performed in the bay between Punta Roja and Punta Luccia off **Vulcano**. Sampling of volcanic rock was not possible due to a technical problem with JAGO's manipulatior arm. The lunch break was used for the transit to **Panarea** Island where the first AUV dive should take place. The AUV team selected a dive site with a shallow bottom depth to ensure that the DVL sensor on AUV ANTON would have a bottom log before the AUV submerges. Meanwhile the cruise leader and Daniele Casalbore applied for a permit to enter and dive within the restricted zone off the Sciara del Fuoco, the northwest slope of the Stromboli volcano, at the coast guard office of Milazzo / Sicily. During the late evening hours, the entire team and crew on board observed the impressive lava throw-offs of the Stromboli volcano.

09 February. JAGO dive 1427-2 with Peter Striewski (pilot) and Tim Weiß (observer) took place at the **Panarea** vent site to test the mini multibeam sensor, attached to JAGO's front, for gas bubble detection and as forward-looking scanning sonar. Afterwards, a short test dive of AUV LUISE was performed. During lunch break the work permit for the restricted zone off Stromboli arrived. After a short transit from Panarea to **Stromboli**, JAGO dive 1428-3 with Jürgen Schauer as pilot and Daniele Casalbore as observer took place in the afternoon. It was a long video and rock sampling transect along the 100-m contour line of the northwestern slope of the volcano. Everybody else on board enjoyed the spectacular view onto the active Stomboli volcano and its periodical and very predictable mini-explosions with small lava fountains and glowing material that rolls down the northwestern slope and often reaches the sea. The first comment of Daniele Casalbore about the dive after disembarking JAGO was that a lifetime dream has become true for him who works since his PhD thesis on the volcanism of Stromboli.

10 February. The early morning hours were used for the transit from Stromboli back to the Baia de Levante of **Vulcano**. After breakfast, JAGO dive 1429-4 with Peter Striewski (pilot) and Nikolas Linke (photographer) as used to explore the submarine parts of the Punta Roja lava flows and produce still photo and video clips from inside the submersible. Although the wind increased in the afternoon, the AUV could be deployed for further test missions in the sheltered bay between Punta Roja and Punta Luccia. After 16:00 the wind bursts became too strong for safe deployments and recoveries. A shift to the southern coast of Vulcano did not provide more wind shelter. The vessel moved to the east coast of **Lipari** into the Baia di Lipari to weather the partly very strong gusts of wind (Maestrale - katabatic wind from northwest).

11 February. The Maestrale wind did not die through the night and prevented all deployments that were planned for that day at a location off the Capo Rossa, **Lipari** Island. The vessel returned into the Baia di Lipari to weather the gusts of wind (Bft 8-9). The team on board spent the time with working on system and software improvements.

12 February. On the next day, the weather allowed two test dives of the AUV in the Baia de Levante off **Vulcano**. In the afternoon, JAGO dive 1430-5 with Peter Striewski (pilot) and Emanuel Wenzlaff (observer) were performed along the submarine Punte Nere lava flows below the La Fossa Cone. The dive was primarily used to measure the performance of the new side rim thrusters on the submersible with an oscilloscope, but also two rock samples were collected.

13 February. The stunning calm and sunny morning was used for a photo, video and drone imaging session of the submersible and the AUVs – both floating at the water surface – in front of FS ALKOR and the La Fossa Cone in the background. It was followed by a dive of AUV ANTON. The lunch break was used for the short transit from the Baia de Levante to the pillow lava field off the southeast cape of **Lipari**. JAGO dive 1431-6 with Jürgen Schauer (pilot) and Karen Hissmann (observer) was dedicated to video document and sample the pillow lava mounds at this site and to test the navigation performance based on USBL data provided on a tablet PC inside the submersible for maneuvering in rugged terrain. The dive among the pillow lava mounds was very impressive. After returning to the Baia de Levante, the EvoLogics seabed transponder EMIL, which also has an integrated acoustic releaser mechanism, was deployed and moored at the seafloor for the first time.

14 February. AUV ANTON was deployed early in the morning for a long test dive. A photograph of the entire scientific team was made in front of JAGO and LUISE before the Italian guest scientist, Daniele Casalbore, was disembarked and transferred by the ALKOR work boat to the port of Vulcano. The seabed transponder EMIL, that had been stationed on the sea floor the day before, was acoustic released and recovered before the lunch break. After this, AUV ANTON surfaced after a successful long dive and was brought back on board before the wind picked up distinctively. In the afternoon no further deployments were possible due to the strong wind gusts (Bft 6-7). The vessel sheltered in the Baia di Lipari for the rest of the day.

15 February. After sunrise, the vessel moved to the Capo Rosso off the westcoast of Lipari Island. AUV ANTON was deployed in the water for a dive from shallow into deep water depth. The mission had to be aborted due to DVL failure. It was therefore decided to move earlier to Panarea for the last stations. After lunch, JAGO and AUV ANTON were deployed off the south coast of Panarea for a rendezvous dive in shallow water depth. JAGO took video images of the cruising and hovering AUV and the camera system on the AUV captured still images of the submersible. The submersible crew used the dive to test the performance of two different HD survey cameras. At the end of the dive, JAGO’s emergency buoy was released to test the rescue procedure. The release was documented with a GoPro camera attached to the submersible. When the rescue buoy had reached the water surface it was recovered by the team on the accompanying work boat. AUV ANTON performed a second final dive at the same location. After recovery and securing all equipment on deck, the official work program of AL533 was finished. ALKOR left Panarea at 15:30 and started the 500 nm transect to La Seyne-sur-mer.

16 February. During the first day of a calm transit, all teams were busy storing data and started packing, and the media team made video- and 360°-camera interviews with some of the cruise participants for a planned documentary. After dinner, they presented some of their plentyful images, for example the spectacular drone flights over the La Fossa Cone on Vulcano and along the Sciara del Fuoco on Stromboli. The vessel reached the Strait of Bonifazius between Sardinia and Corsika at 20:00.

17 February. The rest of the transit remained calm and, just in time before the forecasted strong winds set in, the vessel entered the port of **La Seyne-sur-mer / France**. It docked at 14:36 opposite to the Mediterranean base of the French Marine Research Institution IFREMER. The JAGO-team got in touch with the Head of the Technology System Unit and was lucky to get an appointment for all cruise participants for a visit of the IFREMER Technology Centre the next day. The Captain and the Cruise Leader exchanged and finallized together the cruise summary reports and the teams continued packing and cleaning cabins and labs.

18 February. During the morning, the teams finallized packing the transport boxes and stored them either on palettes or inside the submersible container. At 15:00, the entire team got a very impressive tour on IFREMER’s deep-diving manned submersible NAUTILE and the ROV VICTOR, led by Jan Opderbecke. Jan answered very openly and patiently the many technical and organisational questions of the GEOMAR team. It was a great visit. The cruise participants were disembarked from ALKOR at 18:00 and transferred to the Hotel located at the marina of La Seyne sur-mer.

19 February. In the morning, the cruise participants walked back to the vessel. The ordered mobile crane and the transport trucks arrived at 08:30. The submersible container was transferred onto the pier where the submersible was then placed onto the extended rails in front of the container and then pulled into it by winch. The AUVs and the other boxes were loaded on a separate truck. The team members then said goodbye to the ALKOR crew, walked back to the hotel from where all of them were transferred to the airport of Marseille for their return flights to Germany.

5 Preliminary Results

The cruise lasted in total 11 and ½ days and the total distance travelled was 795 nm. Due to unfavorable wind and sea conditions, the vessel departed two days later from Catania and left the working area one day earlier because of the forecasted strong wind in southern France. A total number of 18 stations were executed. No station work was performed on the transit from the Aeolian Islands to southern France, where the cruise ended in the port of La Seyne-sur-mer (Provence). Vehicle deployments were possible on 7 ½ days out of 9 days in the work area; thus only 1 ½ day was lost for work on deck due to weather. This is a good ratio for a research cruise with a medium sized vessel at this time of the year in the Mediterranean Sea. The Aeolian Islands provide sufficient dive sites close to the coast that are suitable for this kind of equipment tests.

The teamwork and spirit between the science party and the ALKOR crew was excellent and enabled productive as well as enjoyable work on board the vessel. Smaller teams – in this case consisting of in total 23 persons on board – enable close communication and hand-in-hand work between the science party and the crew. The ALKOR crew was also very cooperative and patient in supporting the extensive photo and video shooting on board. Their consent to be photographed and filmed in all kinds of work situations, however, should not be taken as a matter of course during research cruises. Their willingness to cooperate is therefore highly appreciated.

FS ALKOR is a medium-sized research vessel that – at least according to the experiences gained during this cruise – is suitable to serve research projects also outside of its usual operation area in the North and Baltic Sea, even more after some modifications. The vessel proved to be a suitable platform for the deployment of larger scale research equipment like the submersible (weight in air 3 tons) and the Hover-AUVs (ca. 200 kg) in calm seas. The handling of the submersible from on board the ALKOR is, however, at the moment restricted to relatively calm conditions because of the main deck crane. The crane has not sufficient lifting capacity at its outer knuckle boom lifting point. The crane-cable and thus the lifting point had to be relocated to the end of the main / inner arm which shortens the maximum out reach of the crane by at least 3–4 m and reduces its speed. Thus, JAGO had to be picked up and lifted out of the water in a narrow distance of less than 2 m to the ship's side which enlarges the risk of bouncing against the ship's hull and bulwark if the ship roles and pitches. A replacement of the present crane would improve the vessel's lifting capability not only in respect to the JAGO handling with larger safety but also to its general capability to lift heavier gear at sea. It also would enable loading and offloading of equiment heavier than 5 tons on and off deck independently of being assisted by land cranes.

5.1 Dives with the manned submersible JAGO

(K. Hissmann, J. Schauer and P. Striewski)

5.1.1 Short System Description

The GEOMAR-owned manned submersible JAGO can take two persons – a pilot and a scientific observer – to water depths of maximum 400 m (Figure 5.1.1.1) (GEOMAR, Hissmann, Schauer, 2017). The submersible has a compact size of 3x2x2.5m LWH and a low weight of 3 tons that enables shipment in a single 20' ISO container and deployment from a wide variety of support vessels with sufficient crane capacity. The submersible operates worldwide since 1989 and is regularly used from on board the German research vessels including FS ALKOR.

The power for all electrical systems of the submersible is provided by lead-acid batteries. The propulsion system comprises seven electrically powered thrusters that enable precise manoeuvring of the submersible in all directions. Vertical movements are performed by controlled changes of buoyancy, initialized by streaming or releasing a defined amount of water or air into or out of a variable ballast tank. Two large 360-litre diving tanks provide buoyancy and stability when the submersible is floating at the water surface. They are flooded for submerging and filled with air for surfacing.

JAGO is equipped with fluxgate compass, vertical and horizontal sonar, underwater telephone for voice communication (UT), LED lamps, digital video (HD) and still cameras, CTD sensors and a manipulator arm for collecting and handling various sampling devices and instruments. For calculating the submersible's position under water and tracking its movements, different USBL navigation and positioning systems have been used on JAGO in the past. During AL533, devices of the EvoLogics S2C R USBL positioning and communication series were used. One goal of the cruise was further testing of their functionality for exchanging data and messages between the control station on board the vessel and the submersible.

During the dive, the pilot is solely in charge for the safe navigation and maneuvering of the submersible and for the communication with the support vessel. He is also operating the submersible's manipulator arm to handle sampling tools and deploying / recovering instruments, and he is controlling sensors and the video and still cameras for documentation of the environment. This multitasking and – at the same time – responding to the scientific and personal needs of the accompanying scientist, requires a lot of training and experience but also intuition and fine motor skills. Taking a passenger (scientist) to a water depth of up to 400 m and being solely responsible for the safety of both the inhabitants, requires from the pilot full concentration and confidence. The submersible team is presently going through a personal exchange period, since Jürgen Schauer, the long-time chief pilot, is going to retire in the course of this year. His successor and a new second pilot have to be well trained and prepared for their responsible jobs. Pilot training and gaining more steering experience in complex terrain were therefore main aims of this cruise.

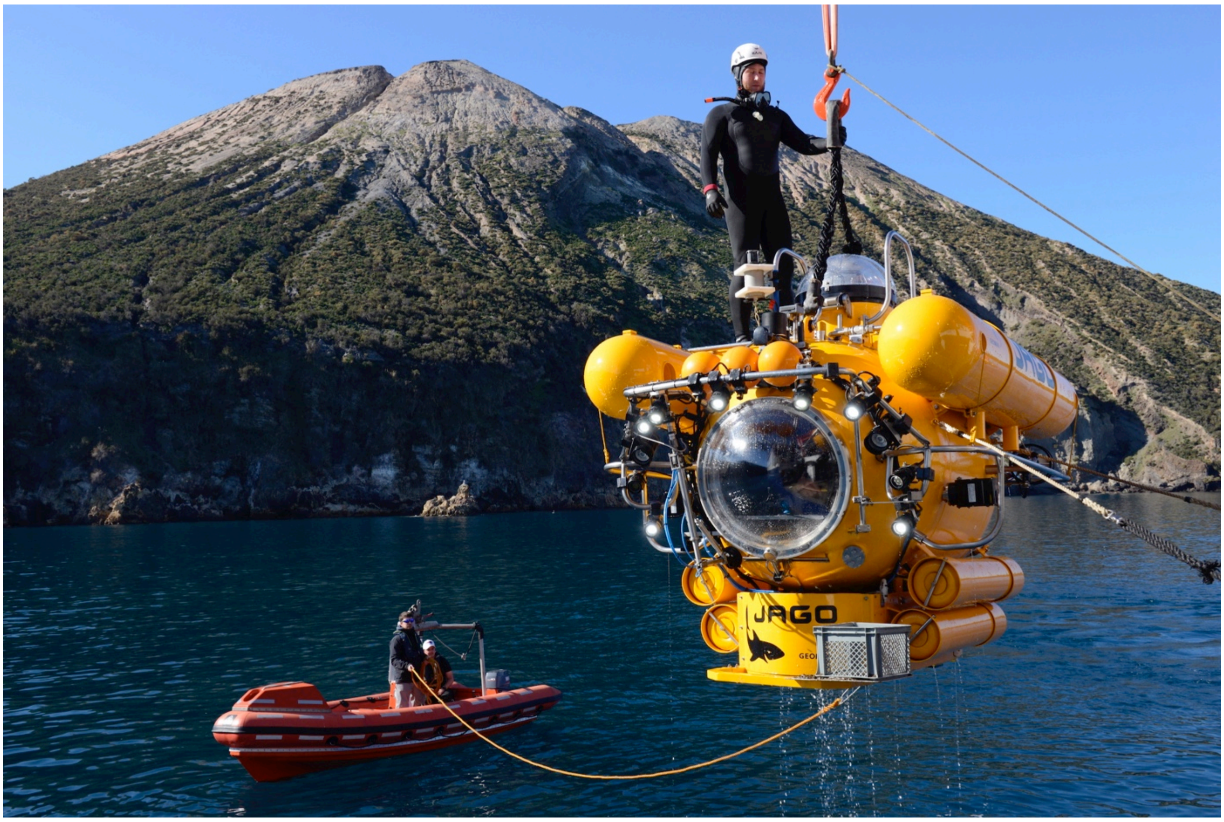

Fig. 5.1.1.1 Submersible JAGO during recovery from a dive in the Baia de Levante between Punta Luccia and Punte Nere off the Aeolian island Vulcano. In the background the La Fossa Cone, the dominant feature on the island (Photo: Karen Hissmann)

JAGO Specifications

- Owner and Operator: GEOMAR Helmholtz Centre for Ocean Research Kiel
- Crew: 1 pilot, 1 observer
- Maximum operating depth: 400 m
- Dimensions: Length 3.0 m, Width 2.0 m, Height 2.5 m
- Personnel cabin dimensions: Length 2.13 m, diameter 1.29 m
- Personnel cabin volume: 2.5 cubic meters
- Weight in air: 3,000 kg
- Maximum payload: 250 kg
- Pressure hull material: Steel
- Viewports: acrylic, 1 bow-window (ø 700 mm), 1 top dome / hatch (ø 450 mm)
- Power supply: lead-acid batteries, total capacity 13 KWh – 24 VDC
- Propulsion: electrically powered thrusters – 3 reversable thrusters at stern, 2 rotational thrusters on starboard and port side, 1 front and 1 aft thruster
- Cruising speed: 1 knot
- Emergency Life Support: 96 man hours
- Safety and Rescue Systems: Emergency drop weight, dead-man's switch, releasable emergency buoy, generation of >500 kg positive buoyancy
- Lighting: 9 multiple positional LED lamps, laser scaling
- Standard equipment: Underwater navigation and positioning system (USBL), voice communication through acoustic underwater telephone (UT), electronic compass, redundant depth sensors, vertical and horizontal sonar, hydraulic manipulator arm, GPS sensor for surface navigation, marine band (VHF) radio for surface communication
- Imaging: Full-HD video cameras for through viewport documentation, hand-held digital still camera, flashes, in-hull hard drive video recorders and monitors
- Scientific sampling equipment: CTD, temperature probes, sample boxes for biological samples or rock collection, water sampler (NISKIN), push corers for sediment samples, fluid and gas samplers, scoop nets and cups, acoustic marker beacons
- Launch & Recovery: man-rated single lifting point
- Transport: 1 x 20' ISO Container or on custom road trailer
- Classification: DNV-GL Hamburg

5.1.2 Overview of the submersible dives and first results

Between February 08–15, 2020, a total of seven dives were performed with the manned submersible JAGO. Dives took place at maximum bottom depths between 50 and 310 meters at 4 different islands. The total dive time was 16 hr during which 12.5 hours of HD-video film was captured. A total of 21 volcanic rock samples were collected at different sites of interest for analyses by the Italian colleagues. Dives were mainly dedicated to train piloting, sampling and video-recording in rugged and steep terrain, and to establish the routine transfer of USBL positioning data from the control station / base on the vessel to the submersible via modem. During one of the dives the performance of the two side rim thrusters was measured in detail with an oscilloscope that was taken on board for the dive. Another dive was dedicated to rendezvous under water with one of the AUVs and to shoot video footages of the AUV (see Figure 10.1.3). During the last dive the release of the rescue buoy was tested.

The advantage of dives without a strong focus on a scientific goal or outcome is that all aspects of science dives can be trained without the expectations of typical research missions. During science dives, the JAGO pilot is usually accompanied by a scientist who often has not been in a manned submersible before and thus cannot assist in any of the required actions. In a two-persons submersible like JAGO, a trainee pilot will be, at some point, on its own, together with a passenger. If needed, he can get verbal support by a senior pilot via the underwater communication system (UT) on board the support vessel. But most of the piloting skills a trainee will gain through learning-by-doing, meaning diving. Peter Striewski is successfully piloting JAGO for a few years now and AL533 gave him another opportunity to navigate JAGO in different and quite challenging terrain. He steered JAGO on five out of the seven dives that were conducted off the Aeolian Islands.

A large improvement for the pilot and the accompanying observer is the availability of the USBL positioning data inside the submersible (see chapter 5.4), which became a routine during AL533 by using the mobile EvoLogics USBL system. During the course of the dive, the submersible crew can see JAGO’s current position now on a tablet PC. The therefore used software SiNAPS (also chapter 5.4) also allows the integration of geo-referenced seafloor maps, e.g. bathymetry maps or multibeam images. The continuously updated USBL positions are projected onto these maps. The pilot can navigate the submersible towards interesting features or around obstacles according to the map. This setup worked extremely well and reliable during AL533. The USBL system and the way it was set up (see chapter 5.4) provided quite good absolute positioning accuracy and thus a smooth track with only few position jumps. In former times, the submersible crew had to be guided towards points of interest by the dive supervisor on board the vessel via underwater telephone communication (UT). The dive supervisor monitors the underwater movements of the submersible on a PC with the same USBL tracking and navigation software. He tells the pilot via UT in which direction he has to navigate and for how far. Sending USBL data from the surface unit of the USBL system to the submersible, however, is only possible with USBL systems that offer a communication link via modem. USBL systems like the ones installed e.g. on RV SONNE or on RV METEOR (both IXblue Posidonia) do not offer this option. At the moment this is only possible with the EvoLogics system and with the Ranger II system of Sonardyne Ltd UK (permanently installed e.g. on RV M.S.MERIAN).

Dive highlights were a geological survey along the ca. 45°-slope at the northwest side of the active Stromboli volcano, the “Sciara del Fuoco” or “fire slide” (see Figure 10.1.2). The survey was in particular for Daniele Casalbore, who joined the dive and investigates the submarine landslides and volcanic eruptions at Stromboli for many years, a unique personal experience. Another dive with impressive geological features was JAGO dive 1431(06) / station 15-2 performed off the southeast coast of Lipari island. Main target of the dive was a field of large and very distinct pillow lava mounds that were up to 30 m high each. Their flanks were covered with long tubular or rounded lava lobes with wrinkled surfaces (pillow lava) (Figure 5.1.2.1). The volcanic rocks were only sparsely colonized by benthic organisms. An impressive encounter was a large bluntnose sixgill shark (*Hexanchus griseus*) at 300 m water depth at the base of one of the mounds. The pillow lava field was a perfect test site for the usefulness and benefits of receiving the USBL positioning data inside the submersible, projected on a multibeam map of the area. It enabled the JAGO crew to navigate the submersible through the cluster of steep mounds towards the shallower saddle between Lipari and Vulcanello islands without verbal support by the dive supervisor on board the vessel.

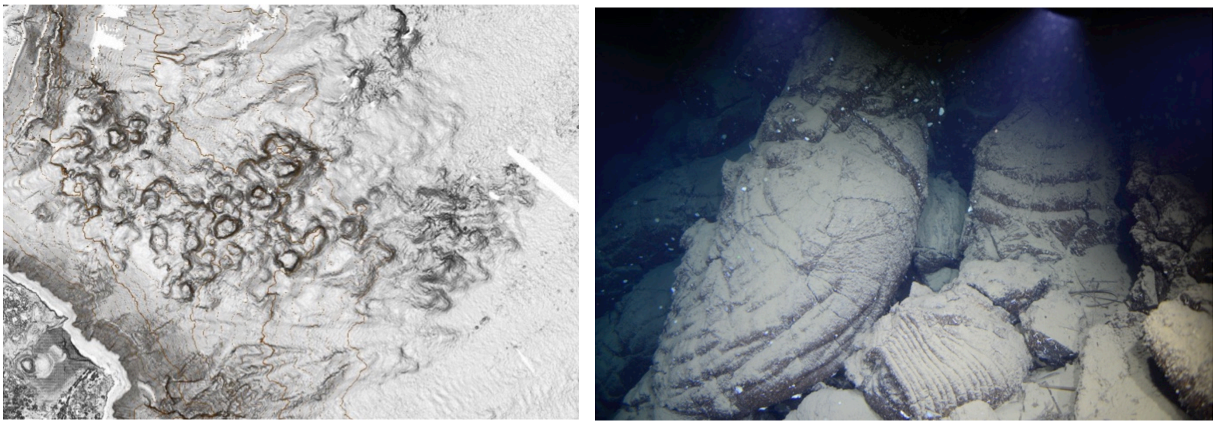

Fig. 5.1.2.1 Field of pillow lava mounds east of the channel between Lipari and Vulcanello island. Left: Multibeam image provided by Daniele Casalbore. Right: Features of pillow lava documented by submersible JAGO at 280 m water depth (Photo: Karen Hissmann / Jürgen Schauer).

5.2 Dives with the AUVs ANTON and LUISE

(M. Rothenbeck, E. Wenzlaff, N. Diller, S. Reißmann, P. Leibold)

5.2.1 Short System Description

AUV ANTON and LUISE

The devices ANTON and LUISE are both so called AUVs – Autonomous Underwater Vehicles. The vehicles of the type GIRONA 500 were developed originally by the GIRONA Underwater Vision and Robotics Lab of the University Girona (Spain) in the early 2010 (Ribas et al. 2012). The AUVs ANTON and LUISE themselves were built by IQUA Robotics, a spin-off company of the Lab. Both vehicles joined the GEOMAR AUV group in 2018/19 as part of the HGF infrastructure project MOSES. The GEOMAR AUV group is operating since 2008 a fast torpedo-shaped AUV for mapping of large seafloor areas during long missions (ABYSS, REMUS 6000 type). In contrast, the GIRONA type AUVs are so called hover capable AUVs, small and lightweight AUVs that are designed for slow speed manoeuvring to gather high-resolution data in small areas or in specific locations (Figure 5.2.1.1).

ANTON and LUISE have a maximum operating depth of 500 m and they are reconfigurable. Each vehicle is composed of an aluminium frame, which supports three torpedo-shaped hulls of 0.3 m in diameter and 1.5 m in length as well as other elements like the 5 thrusters. The two upper hulls contain the main electronics housing, the Inertial Navigation System (INS), the acoustic modem, the pressure sensor, the antenna, several connectors and flotation foam. The lower compartment contains the heavier parts like the battery, the Doppler Velocity Log (DVL) and the payload section. The overall dimensions of the vehicle are 1 m in height, 1 m in width, 1.5 m in length and the total weight is less than 200 kg. The particular arrangement of the components clearly separates the vehicle's centre of gravity from the centre of buoyancy, which is not the case in a typical torpedo shaped design. The vehicle gains passive stability in pitch and roll by this separation, making it e.g. suitable for slow imaging surveys.[1]

[1] http://iquarobotics.com/girona-500-auv, 2020

One of the main reasons for GEOMAR to choose this AUV type was the AUV software architecture COLA2. Cola2 is an open source software package. It enables the GEOMAR AUV group to integrate different sensors or adapt the vehicle according to the diverse needs in marine science. One of the goals is that the vehicle interacts with its environment or with other vehicles and devices. For this kind of interactions while submerged, the GEOMAR AUV group is presently developing the command and control software BELUGA (see below), which was extensively tested during AL533.

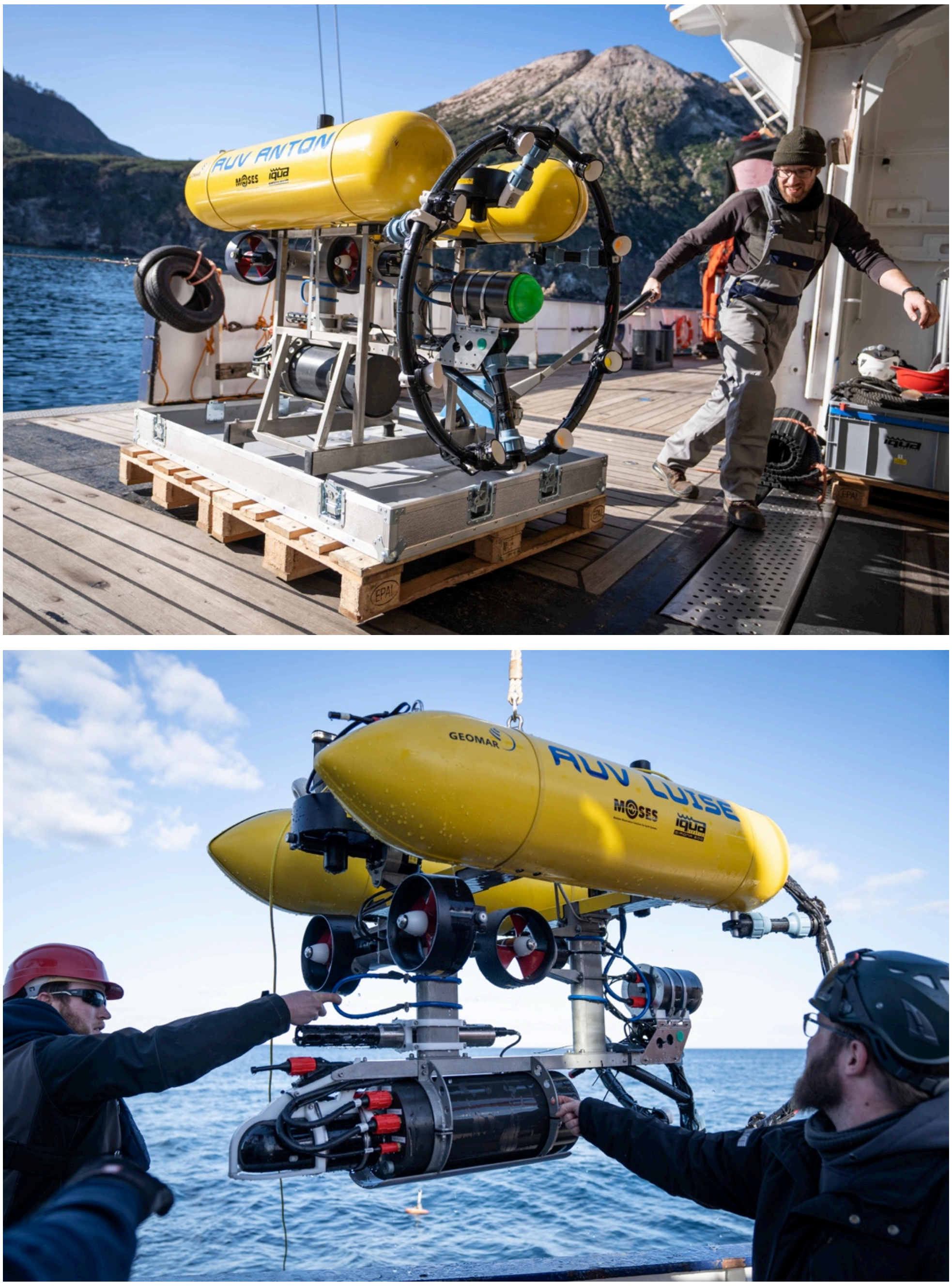

Fig. 5.2.1.1 Hover capable AUVs ANTON (top) and LUISE (below) on board the RV ALKOR during AL533, both with CoraMo camera system attached to the front (Photos: top Nikolas Linke / below AUV Team).

The standard sensors of AUV ANTON and LUISE, which are installed on each mission, are:

INS - iXblue Phins Compact C3
The internal navigation unit that processes sensor data and provides position information. The error of this INS is in range of 0,15° for heading and 0,05° for roll and pitch. This leads to a 0,3% DT position accuracy (if aided by DVL).
DVL - Teledyne RDI Explorer 600kHz
This device measures the vehicles' velocity relative to the sea floor and its altitude.
CTD - Sea-Bird SBE 49 FastCAT
This measurement device acquires the conductivity, the temperature and the pressure of the water and calculates the sound velocity.
Pressure sensor - Valeport ultraP
This sensor measures the pressure and converts it to water depth.
USBL[2] - Evologics S2CR 18/34
The Evologics S2CR 18/34 modem combines underwater acoustics and positioning.
GPS - Quectel l86 GNSS module
The GPS is used to determine the vehicle's absolute position at the surface.

Optional payload sensors are for example:

MBES[3] - Imagenex 837B DeltaT 4000
The optionally mounted multibeam sonar is used for seafloor mapping. During AL533 the MBES was only used on the submersible JAGO (See chapter 5.6).
Camera - CoraMo Mk II
Down or forward-looking camera system for photographic surveys with an image rate of up to 2 images per second with a resolution of 12.34 MP. For illumination, CoraMo is connected with 8 high power LEDs. The CoraMo Camera was the standard payload on each AUV dive during AL533.

IQUAview

IQUAview is a graphical user interface (GUI, Figure 5.2.1.2) developed by IQUA Robotics that allows operating the GIRONA500 type vehicles. IQUAview provides a front-end to the COLA2 software architecture. It enables the operators to communicate with the robot, to configure a basic set of parameters, and to plan and monitor missions by using an intuitive graphical interface[4]. IQUAview is based on QGIS, an open source Geographic Information System (GIS). This GUI was delivery with each of the GIRONA500 vehicles. Unfortunately, it allows to communicate with only one vehicle at a time. This was one of the reasons why BELUGA was developed. IQUAview, however, still has to run in parallel to BELUGA since some features like mission planning or setting parameter has not been implemented in BELUGA yet.

[2] USBL – Ultrashort Baseline (See chapter 5.4)
[3] MBES – Multibeam Echosounder
[4] https://bitbucket.org/iquarobotics/iquaview/src/master/, 2020

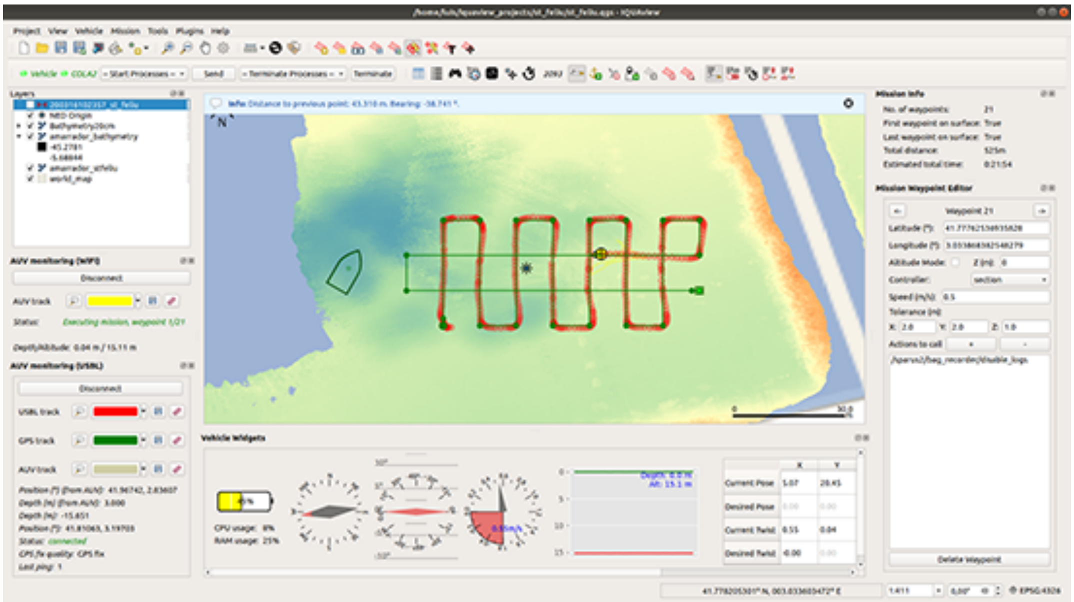

Fig. 5.2.1.2 Graphical User Interface IQUAview

BELUGA – Marine C&C System

BELUGA is a project of the GEOMAR AUV group, which encompasses not only the development of a software tool to operate the AUVs in parallel, but is supposed to create also an infrastructure for future positioning and communication features for different types of underwater vehicles and equipment. The BELUGA project is part of the project « Robotische Exploration im Netzwerk » funded by the Werner Petersen Stiftung Kiel.

Like IQUAview, also BELUGA consists of a GUI, however, it is not just the graphical interface of COLA2. BELUGA, instead, has a complex backend that is able to communicate with COLA2 on the vehicles via the communication language protocol DCCL[5] (Schneider et al. 2010). In this way BELUGA is able to communicate not only with one but with several platforms that understand this language protocol. Originally BELUGA was supposed to implement the language protocol CCL (Stokey et al. 2005), which is part of the software VIP (Freitag et al. 2005), the GUI of the GEOMAR REMUS6000 AUV. But DCCL is more flexible in terms of message size. Since QGIS is a very common GIS tool and since IQUAview also uses it, the navigation map of the BELUGA frontend is based on this open source tool.

In summary, BELUGA consists of a base (control station) and several platforms, as on AL533 two GIRONA500 AUVs and two EvoLogics transponders. The base encompasses the backend, the frontend, the acoustical USBL modem and the operator. The frontend was not ready during AL533, so only a rudimentary first version was used to visualize the data of the backend. Each platform (AUV, transponder, JAGO) is equipped with an EvoLogics S2CR 18/34 Modem. The modem enables acoustic communication with the base and with the other platforms. Aside from that, the modem is also a USBL beacon, its relative position under water is detected by the USBL modem of the base on the ship (see section 5.4). The positions of the submerged platforms are calculated and provided by SiNAPS, a software tool of EvoLogics (section 5.4). SiNAPS runs parallel to BELUGA and is used by the BELUGA backend. The network layer EvINS – a polling protocol – was also implemented. EvoLogics developed this network protocol

[5] DCCL – Dynamic Compact Communication Language

package in an externally funded project. It was initially integrated into the EvoLogics software by another party and their approach was rather experimental. During AL533, EvINS was implemented properly. Now, the base on board the vessel is all the time the requesting part and the submerged platforms answer.

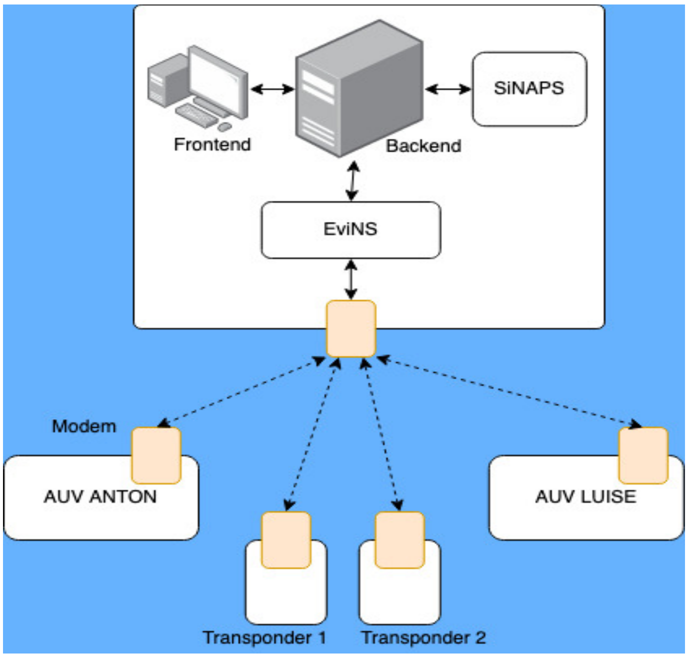

Fig. 5.2.1.3 BELUGA structure during AL533

5.2.2 Overview of the AUV missions performed during AL533

<u>Trim Test – 07.02.2020 - Station 3-1</u>

The first AUV deployment was a trim test for the AUV LUISE on February 07. The goal of that test was to gain a good balance of the vehicle in Mediterranean water. The deployment was performed with the starboard aft crane and it was also a handling test for the setup of the launching and recovery gear.

<u>Tripple Camera mission – 08.02.2020 – Station 5-1</u>

At Panarea, AUV ANTON did several missions in a row to determine the best setting parameters for the attached camera system. In addition, the first acoustic messages were exchanged through the BELUGA system. The messages sent from the AUV to the base showed the status of the vehicle like its internal INS position and immersion depth. The actual position of the vehicle was measured via the USBL modem attached to the ships' moon pool.

Stat. #	AUV Mission	Start	End	Duration	Data		Max Depth	Remarks
					# Pics	Size		
5_1	Anton 85	12:20	13:15	55 min	3220	7.2 GB	40m	Different altitudes 10m-40m Fixed camera settings
5_1	Anton 86	14:30	15:00	30 min	182	493 MB	40m	Different altitudes 10m-40m Automatic settings, only 1 Pic/10s
5_1	Anton 87	15:21	15:54	33 min	187	219 MB	40m	Different altitudes 10m-40m Fixed settings 1 Pic/10s

Acoustic Test AUV LUISE - 09.02.2020 – Station 7-1

At Panarea, AUV LUISE was deployed for a camera test dive which had the purpose to test acoustic commands which were sent from the top unit to the vehicle. The dive had to be aborted due to problems with the vehicle's internal computer.

	AUV Mission	Start	End	Duration	Data	Max Depth	Remarks
7_1	Luise 09	10:30	11:15	45 min	-	100m	Luise acoustic test - > vehicle error -> no communication no response from AUV

Acoustic Test AUV ANTON - 10.02.2020 – Station 10-1

The dive was separated into several missions. They were used to 1) test the USBL positioning, 2) the descending without DVL support (bottom lock), 3) to overcome the drift in position accuracy and to test the USBL aided position update while the AUV is descending or ascending through the water column and has no DVL bottom lock and 4) to check the emergency commands.

	AUV Mission	Start	End	Duration	Data		Max Depth	Remarks
					# pics	Size		
10_1	Anton 88	12:29	12:40	10 min	3826	8.7 GB	200m	Acoustic GoTo -> Strong drift under Water -> aborted
	Anton 88_1	13:30	14:44	14 min	1204	3.1 GB	20m	Test for acoustic commands
	Anton 88_2	13:54	14:25	29 min	1410	3.2 GB	50m	Drift test -> strong drift (200m)
	-	-	-	-	566	1.5 GB	-	Parked in water on surface
	Anton 88_3	14:54	15:00	6 min	131	222 MB	20m	Test for acoustic abort command -> no response -> changed settings
	Anton 88_4	15:13	15:21	8 min	194	290 MB	20m	Test for acoustic commands with new settings -> no response
	Anton 88_5	15:28	15:35	7 min	211	322 MB	20m	Test for acoustic commands with new settings -> no response
	Anton 88_6	15:41	15:46	4 min	212	169 MB	20m	Success -> vehicle got USBL fixes for navigation update

Water Column Test AUV ANTON – 12.02.2020 – Station 11-1

The objective of this dive was to descend to deeper water without DVL bottom lock support but with USBL position update. The dive went well after a first minor problem with the vehicle's pressure sensor.

	AUV Mission	Start	End	Duration	Data		Max Depth	Remarks
					# Pics	Size		
11_1	Anton 89 fail	9:13	9:36	23 min	-	-	-	Pressure Sensor Fail -> Recovery before Mission
12_1	Anton 89 Pre	12:04	12:15	11 min	211	447 MB	15 m	Short USBL Test
	Anton 89	12:16	13:16	1h	3316	5 GB	200 m	Early Abort due to Mission Timeout -> but successfull

Deep dive ANTON and Test LUISE – 13.02.2020 – Station 14-1

Both AUVs and also the submersible JAGO were deployed for a photo, video and drone image shooting session at the water surface. Afterwards AUV ANTON was sent on a deep dive for a photo shooting survey with the CoraMo camera. After all vehicles were recovered, the EvoLogics seabed transponder EMIL was deployed and moored on the seafloor.

	AUV Mission	Start	End	Duration	Data		Max Depth	Remarks
					# pics	Size		
14_3	Luise _ shooting				1167	3 GB		Fotoshooting from Jago and AUVs
	Luise shooting 2				277	632 MB		
	Luise Surface Mission	8:30	8:36	6 min	269	522 MB	0	Surface Mission as Test -> Success
	Luise USBL Test	8:38	8:42	5 min	2	3.9MB	15 m	Short Mission -> aborted -> main PC shutdown
	Anton Shooting				334	859		Fotoshooting from Jago and AUVs
	Anton_90	9:18	10:40	1h 22min	4511	8.54 GB	200m	Deep dive foto mission

USBL Test and Photo Survey – 14.02.2020 – Station 16-2

The aims of this dive of AUV ANTON were to test the USBL based positioning throughout the entire dive and to carry out a long dive for several hours which has not been performed before. All missions were successful.

	AUV Mission	Start	End	Duration	Data		Max Depth	Remarks
					# Pics	Size		
16_2	Anton 91 pre mission 1	5:26	5:32	6 min	196	451 MB	15 m	USBL Test mission
	Anton 91 pre mission 1	5:34	5:41	7 min	192	444 MB	15 m	USBL Test Mission
	Anton 91	5:44	11:09	5h 24 min	17140	38.91 GB	200m	Long survey mission to drain battery

Lipari Deep Dive / Panarea JAGO Meeting – 15.02.2020 – Station 17-1 + 18-3

The aim of the first dive off Lipari was to perform a long dive from shallow into deeper water. The dive had to be aborted due to a DVL failure (no bottom lock) at the beginning of the dive.

	AUV Mission	Start	End	Duration	Data		Max Depth	Remarks
					# Pics	Size		
17_1	Anton_92	07:20	9:20	-	2454	9.5 GB	100m	Not a real mission because AUV had no bottom lock. We did 6 attempts

The first of two dives off the south coast of Panarea was a mutual dive of AUV ANTON and submersible JAGO to meet underwater and to shoot images of one another. The DVL, that did not function the before, was now working fine on ANTON. The last dive of AUV ANTON was used to test the new acoustic GOTO command which enables the operator on board the vessel to send the submerged AUV to a specific position.

	AUV Mission	Start	End	Duration	Data		Max Depth	Remarks
					# Pics	Size		
18_3	Anton_93	11:40	12:57	1h 17 min	4268	14.6 GB	55 m	Jago and Anton meeting under Water. DVL Test
	Anton_94	13:52	14:00	8 min	1034	3.4 GB	20 m	Acoustic goto with Anton

5.2.3 Preliminary results and outcome of the AUV test missions

During AL533, both AUVs performed in summary 11 dives with 22 missions and took over 100.000 photographs. The most important outcome of the cruise for the AUV-team are the experiences made during the cruise. They comprise routine procedures like getting the vehicles ready, put them into a mission and retrieve the collected data. The experiences made so far show that features like low vehicle velocity and open source software provide not only new opportunities but also involve huge technical challenges. The dives revealed many weak points in the hard- and software of the vehicles. This information will help the GEOMAR AUV group to improve the system and make it more reliable for future cruises.

Especially the dive to 200 m off Vulcano island and the combined JAGO and ANTON dive showed the benefits of the USBL driven navigation and communication network through the BELUGA system. The system proved its capability to connect different under water devices in one network and exchange data between them. In the future, the team will work on a more controlled descending process especially when the vehicle is moving though the water column and has no DVL support. The BELUGA network will be further developed and hopefully will become a useful tool to improve AUV positioning.

5.3 Camera System CoraMo MK II and its use for pelagic imaging surveys

(E. Wenzlaff, M. Rothenbeck, H. Hampe)

The main goal of the AUV part of the cruise was the testing of the BELUGA software tool and its capability to manage the acoustic communication between the control station on the vessel, the two AUVs ANTON and LUISE and the acoustic transponders on the seafloor. In addition and in order to prevent an empty payload area, the AUVs were equipped with the new camera system CoraMo MK II. The GEOMAR Research Group *Midwater Ecology*, headed by Dr. Henk-Jan Hoving, is operating the pelagic in situ observation system PELAGIOS which is an ocean observation instrument that is slowly towed horizontally through the water column behind the ship on a conducting cable (Hoving et al. 2019). Henk-Jan Hoving and the AUV group had the idea to test the suitability of AUVs for midwater surveys and to compare it with a tethered system like PELAGIOS. A forward-looking camera system that would take photographs of organisms in front of the vehicle while the AUV is cruising through the water column or above the sea floor, would not disturb or interfere too much with its primary tasks. The camera system CoraMo MK II, which is a development project of the AUV group, was adapted for photo surveys with the AUVs in the water column. The surveys should help to evaluate the suitability of the AUVs as tools for midwater ecology research.


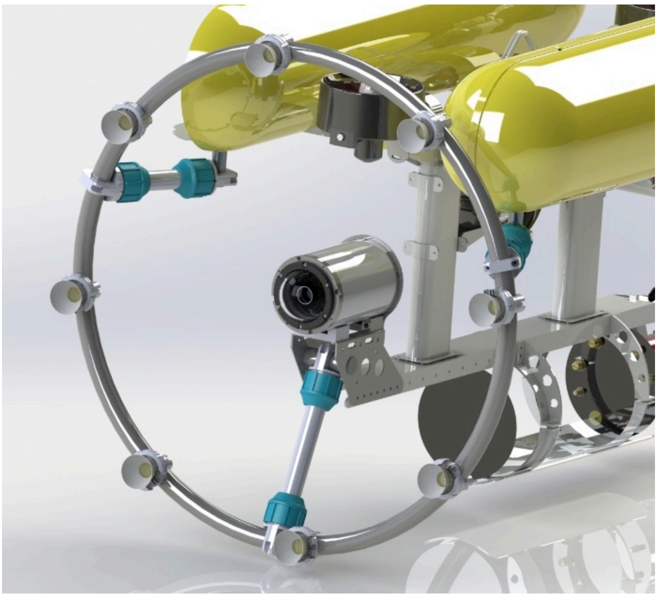

Fig. 5.3.1 CoraMo camera without the cylinder of the pressure housing (left); 3D image of the camera system including the LED ring (right)

The CoraMo Mk II (Figure 5.3.1) is an independent camera system with 8 scalable high power LED-lamps. It was developed by the GEOMAR AUV group originally for the AUV AEGIR and is a further development of the DSC camera for the deep-sea AUV ABYSS (Kwasnitschka et al. 2016). The CoraMo Mk II is an improved version of the first system and especially desigend for usage on the GIRONA 500 AUVs. For testing its applications for midwater ecology research, the camera was mounted in a forward looking way on the main frame of the AUV and surrounded by a ring of LED lamps (Figure 5.3.2). The ring has a diameter of approximately 1.0 m and carries 8 LED lamps in equal distance to one another.

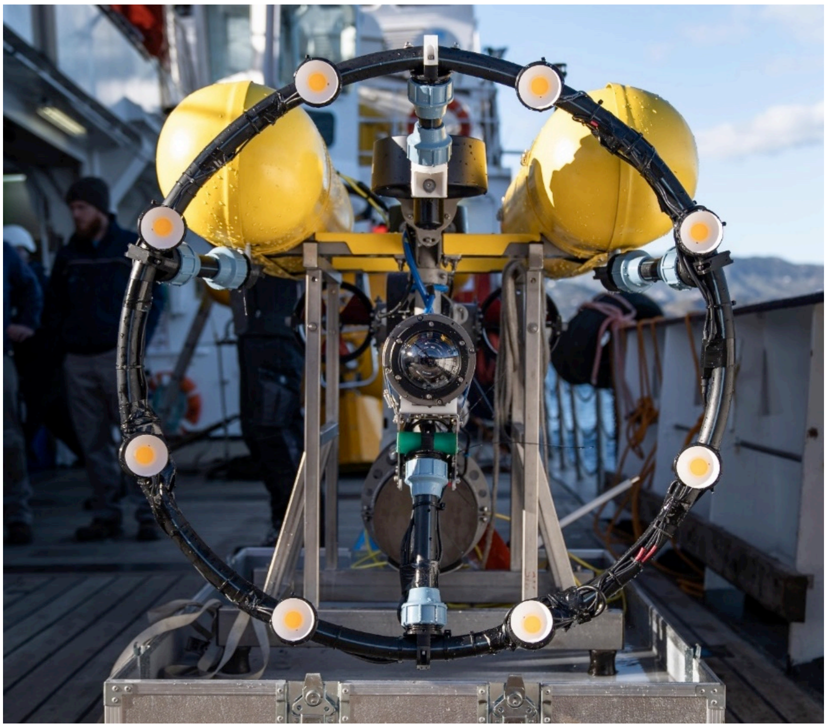
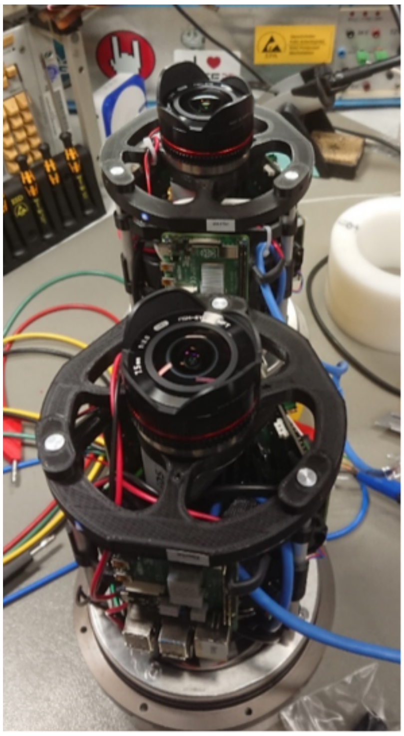

Fig. 5.3.2 CoraMo Mk II mounted on a G500 type AUV on deck RV ALKOR (left), inner camera chassis in the GEOMAR lab (right).

The LED lamps are not constantly on, the camera triggers their turning-on and -off. When a picture is taken, the LEDs will flash shortly to provide illumination of the area in front of the AUV. The camera runs on a Raspberry Pi4 mini-PC that can be accessed via ethernet to change settings. In the present development stage, the focus and the zoom of the camera lense are not changeable via ethernet but illumination, shutter speed, main gain and colour gains are adjustable. The positioning and heading of the LED lamps have to be adjusted manually prior to vehicle deployment. Camera settings and light intensity can be changed while the AUVs are under water. This enabled test dives with a series of different settings in the course of a dive. The specifications of the camera system are summarized below. Every single picture taken has its own set of meta-data that is copied into a meta-data file collection. AUV time, position, depth, altitude and attitude as well as camera and flash settings are parameters of each data set. The data sets can be downloaded as an csv or Excel sheet after each dive.

Technical Specification CoraMo MkII camera system

Camera: IDS uEye UI-3000SE (USB 3.1 Gen. 1 uEye SE)	
Interface	USB 3.1 Gen. 1
Sensor	Sony CMOS IMX253
Optical class	1.1"
Resolution	12,34 MPixel
Frame rate	31,0 fps
Resolution (hxv)	4104 x 3006
Lens: Samyang 7.5mm Fisheye f/3.5	
8 LED Flashes	
PC: Raspberry Pi 4	
RAM	4GB
Memory	128GB
Operational System	Ubuntu with ROS
Automatic linkage of photographs (.jpg /.png) with AUV data	
	Position in Lat/Long
	Time
	Vehicle Depth / Altitude
	Roll / Pitch / Yaw
	camera and flash settings (see list with meta data)
100 mm Domeport	
Depth rating of the camera housing: 500 m	

Since positioning and the communicating with the AUVs did not yet run sufficient smoothly and reliable, test dives were only performed during day time and to a maximum water depth of 50m. The upper 50 meters of the water column, however, are part of the euphotic zone, so that the camera had to cope with a lot of sunlight. For adjusting the settings of the cameras properly, a night dive would have been better but this was not an option under the given circumstances. After a couple of surface dives with exposures to too much sunlight, it was possible to do a dive down to 140 m depth. Unfortunately, the pictures that were taken at this depth were too dark and very blurry. The orientation of the LED flash lamps were not correct, the selected trigger speed was with 8ms too slow and the illumination therefore too weak.

As a next step the illuminated zone in front of the AUV was put closer to the camera and the orientation of the LED lamps were set similar to the orientation of the lamps on the PELAGIOS system, which improved the illumination performance. The photographs were brighter and more evenly illuminated, but the trigger speed was still too slow. In a last step, the trigger speed and the brightness of the LEDs were increased and the main gain was set higher so that it became more sensitive for the light intensity.

The vehicle speed is also a factor that has an influence on image quality. The initial vehicle speed of 1.0 knots seemed to be too fast to achieve sharp images of animals. Therefore, several velocities were tested (hovering, 0.1m/s, 0.2m/s, 0.3 m/s, 0.4m/s). At slower speeds, the pictures were sharper, not so blurry and especially small animals were more in focus. Unfortunately, after finally finding the best camera settings, both AUVs started showing increasing technical issues and no more time was left for collecting more images with the camera system.

Example of meta-data attached to each picture made with the CoraMo Mk II

date & time	15.02.2020 08:45	intensity_channel_B	240
image_width	4104	intensity_channel_C	240
image_height	3006	intensity_channel_D	240
color_mode	rgb8	intensity_channel_E	240
auto_gain	0	intensity_channel_F	240
master_gain	50	intensity_channel_G	240
red_gain	50	intensity_channel_H	240
green_gain	10	flash_max_pulse_length	4.5
blue_gain	55	seconds	1581756334
auto_exposure	0	longitude	14.963944
exposure	4.014541	latitude	38.498318
auto_white_balance	1	depth	60.70575
white_balance_red_offset	0	altitude	30.91
white_balance_blue_offset	0	yaw	1.994754
flash_delay	-80	pitch	0.092991
flash_duration	1000	roll	-0.100444
all_channels	1	x_velocity	0.053781
channel_A	0	y_velocity	0.046134
channel_B	0	z_velocity	-0.371641
channel_C	0	temperature	15.0647
channel_D	0	salinity	37.921501
channel_E	0	pressure	620620
channel_F	0	sound speed	1511.313965
channel_G	0	conductivity	4.61967
channel_H	0	isovalue	-1
intensity_channel_A	240	strategy debug	

The outcome of the cruise in respect to the camera testing are two successful dives with usable pictures of the water column and of JAGO (Figure 5.3.3). Unfortunately, there were too few pelagic animals in the water column that could be captured on photographs and thus used to judge about the quality of the camera-settings.

For further testing it would make sense to perform more dives in deeper waters and at night. This would help to improve the adjustment of the camera and light settings. The present camera system uses a fisheye lense. For a next test it would be good to try a wide angle lense and compare the results of the two lense types. Finally, like on the PELAGIOS systems, video instead of still photographing could be an alternative. Video recording, however, needs constant illumination which means higher power consumption an could therefore be a limiting factor.

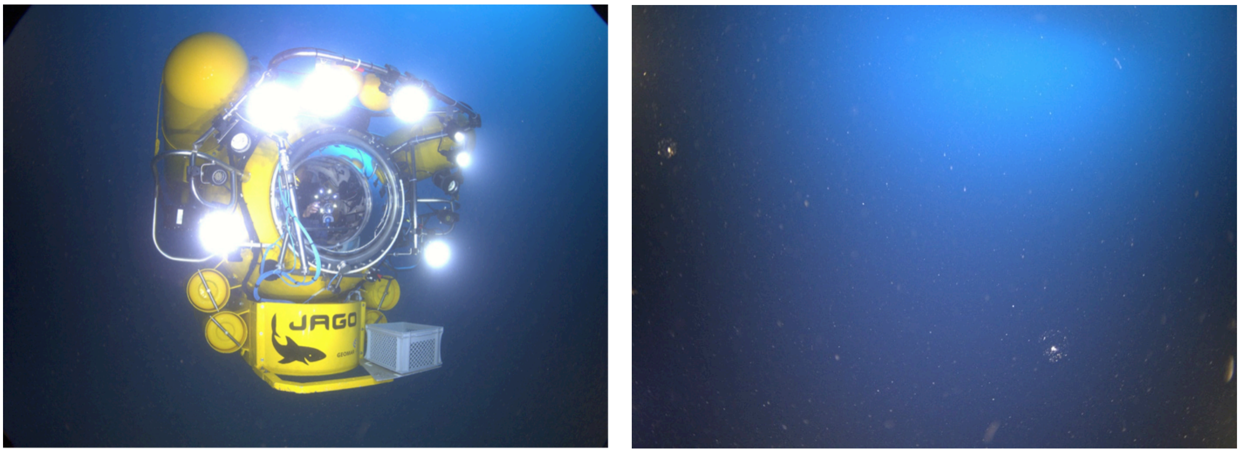

Fig. 5.3.3 Examples of images made by the CoraMo camera attached to the AUV. Left: submersible JAGO at 60m water depth, right: water column with a few pelagic organisms

5.4 EvoLogics USBL, network setup and comparison of software

(Tim Weiß)

<u>EvoLogics USBL</u>

The AUVs ANTON and LUISE, the submersible JAGO and the seabed transponders are all using the same acoustic underwater navigation and communication system from EvoLogics GmbH Berlin. It provides ultra-short base-line (USBL) positioning and full duplex communication links. For the calculation of underwater positions, a system consists of an USBL top-side modem (S2CR 18/34 USBL) and one or more acoustic modems (S2CR 18/34) attached to each of the underwater vehicles or devices (Figure 5.4.1). The USBL top-side unit sends requests to the acoustic modem mounted on the target, and the modem returns a response. The running time of acoustic signals between USBL and acoustic modem is then used to calculate the distance between the USBL and the acoustic modem. Together with the direction from where the responses were transmitted, this information is used to determine a relative position for the submerged target. By incorporating GPS information and the orientation of the top-side modem in relation to the ship's heading, an absolute position with latitude and longitude coordinates is determined.

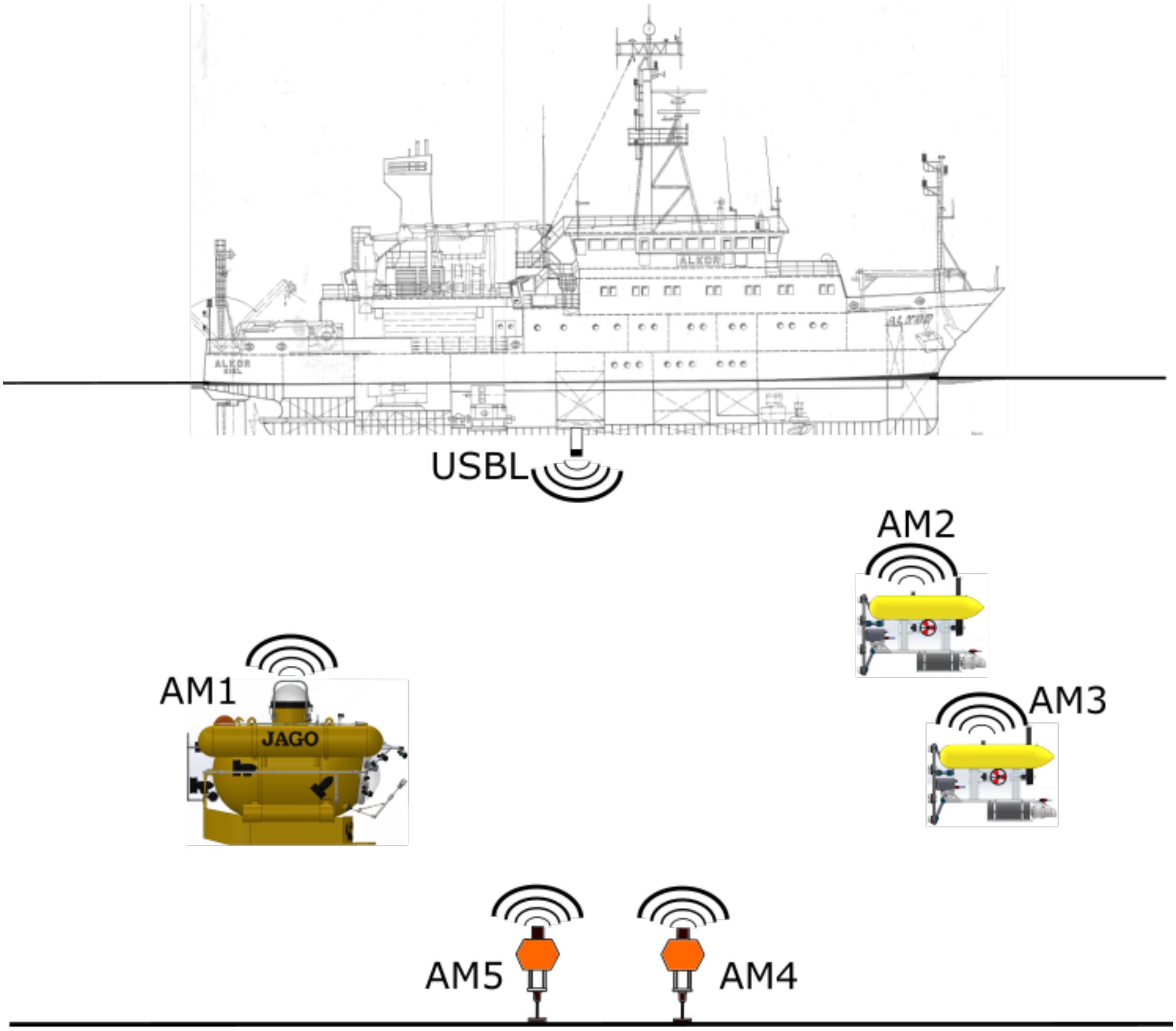

Fig. 5.4.1 Schematic view of an ultra-short base line system (USBL) and acoustic modems (AM)

Network Setup

Since the model of the USBL modem was the same on the AUVs and on JAGO, the setup of the positioning network had to be adapted respectively (Figure 5.4.2). Three networks with different IP address ranges were used. The ship network provided the ships GPS position and heading via TCP network ports. The USBL network was needed to establish a connection to the USBL modem which is configured with a static IP address. Further, this network was used by the AUV team for different software systems (Evologics SiNAPS, IquaView, BELUGA). Another network (JAGO network) served for the distribution of USBL positions to software clients used by the JAGO team (OFOP, QGIS, SiNAPS). NMEA strings were sent via UDP to the ship network and to the JAGO network. On the bridge of RV ALKOR, a computer was running the EvoLogics navigation and positioning software SiNAPS to ensure that the officer on watch could see JAGO's position during dives. Within the JAGO network three different products of observer software were used to compare their capabilities.

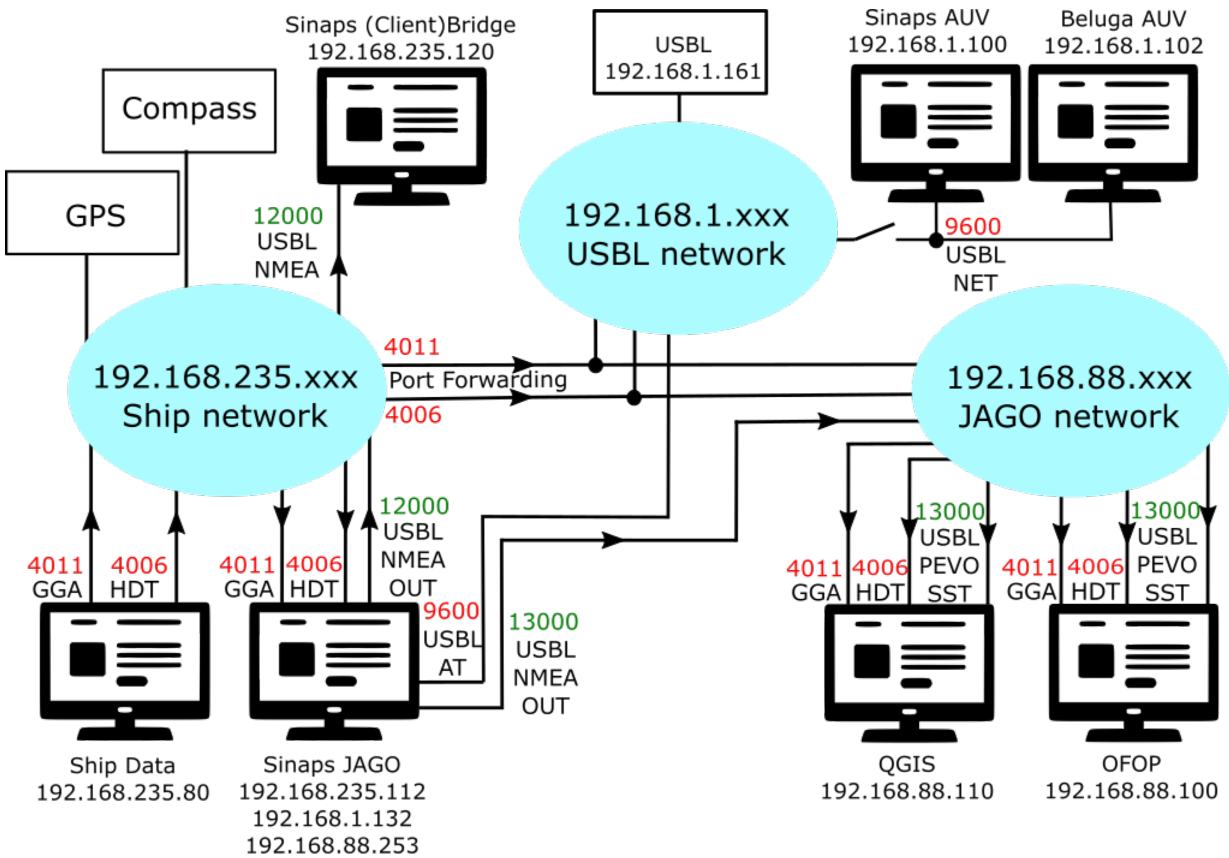

Fig. 5.4.2 Network setup (UDP ports in green, TCP ports in red)

<u>Comparison of JAGO Observer Software</u>

EvoLogics SiNAPS

SiNAPS is the custom control software of EvoLogics that is purchased with each system. The software runs locally on a standard PC as a web server. The graphical user interface is accessed in a web browser. The USBL and acoustic modems are configured in SiNAPS. Ships information, e.g. GPS positions, heading etc., are configured in SiNAPS as well. The USBL is activated/de-activated via the software to start/stop pinging. The positions of each acoustic modem and of the ship are displayed in a map view. Position information can be distributed via UDP, TCP and serial ports as NMEA like text messages. In the latest (beta) version of SiNAPS it is possible to integrate custom maps by providing map tiles in a standardized format.

SiNAPS is streamlined for EvoLogics products and works very well within the EvoLogics product world. It has a modern interface and continuous updates show, that the software development is still active and in progress. So far, there is still a lack of support to create mission plans. Especially a convincing feature for setting and storing waypoints would be important. Also, the software documentation is slightly outdated and limited. As with every proprietary software, a strong dependency to the manufacturer exists. At the moment, the feature set is not rich enough to use it completely without any additional software for mission or dive planning. Since SiNAPS is also the control software for the USBL modem, it needs to run during every deployment, also if another navigation software is used in parallel. For the JAGO dive supervisor at the surface control station, SiNAPS gives very valuable and essential information about the current status of the system, e.g. connections and position update rates. The web server/client architecture of SiNAPS furthermore allows display of the current underwater situation on different computers, like the one installed on the bridge for tracking JAGO.

SiNAPS is currently also the software that is used within the submersible. The ability to send data to the submersible via an acoustic link makes it possible to retrieve the position on a tablet PC inside the submersible during the mission. This mode is called inverse USBL and can be configured via EvoLogics SiNAPS software.

Ocean Floor Observation Protocol OFOP

OFOP is a software package to support marine scientists before, during and after deployments / missions of scientific equipment (Huetten and Greinert, 2008, http://www.ofop-by-sams.eu/). Originally, it was built to annotate video material generated during ROV dives and OFOS surveys in real time. Over the years, it evolved to a tool for planning and monitoring ROV and submersible missions, multibeam survey planning and as a post-processing annotation tool for video material. For several years, OFOP has been used by the JAGO team to track JAGO's position during dives. OFOP supports several protocols from different USBL manufactures.

Video material can be replayed in synchronization with the recorded track. Hence, it is possible to annotate the video after the dive, which is crucial for video material collected by a submersible that is not connected to the ship by a data cable. Furthermore, OFOP offers several helpful tools for planning the mission (e.g. UTM-to-LAT/LON converter, distance measurements, survey planning tools).

However, in recent years, the development of OFOP has declined due to limited development resources. The user interface and its operation are not state-of-the-art anymore. OFOP supports geo-referenced maps, but only in its own format. Therefore each map needs to be calibrated / geo-referenced with OFOP which can introduce errors.

QGIS

QGIS is a commonly used geo information software with a very rich set of features. It is widely spread among marine scientists. QGIS is completely free and open source. It also offers an option to add own software modules in form of a plug-in, which then can be called by the main application. The real time tracking of targets (incl. heading) is not supported by QGIS, but a plug-in called PosiView (developed by MARUM) supports this feature. PosiView does not support the EvoLogics output format. But since PosiView is also an open source software, it was possible to develop a module to decode EvoLogics messages and display them on the map in QGIS. In comparison to the other two candidates, QGIS is very promising because it has many features, a robust code base and the convenience to add own software modules.

5.5 EvoLogics Seabed Transponders

(Patrick Leibold)

To extend the underwater network at GEOMAR and to support the Girona500 AUVs during scientific missions, two acoustic seabed transponders were purchased just before the shipment of the AUVs for the AL533 cruise. The idea is to deploy the transponders as stationary underwater network nodes, anchored at the seafloor. They then should serve as communication relays and localization beacons by using their integrated acoustic modems. The transponder relay should support the localization of AUVs underwater and interactions for all kinds of underwater vehicles. Due to the fact that the transponders were delivered so shortly before the shipment of the AUV equipment, AL533 was mainly used for initial tests. These tests aimed to get first experiences in handling the transponders and to check their functionality and performance. During AL533, a first version of a customized transponder software was also completed, which will control and monitor both the operation of the transponder and the communication with the ship and the AUVs.

Both transponders are S2C R 18/34 Seabed Transponders, manufactured by EvoLogics GmbH in Berlin. The main component of this kind of seabed transponder is an acoustic EvoLogics S2C R 18/34 modem embedded in a block of buoyancy foam. The transponders were selected because they provide full compatibility with the existing modems on both of the Girona500 AUVs. Like the modems on the AUVs, the selected model can be located three-dimensionally in the water column from another, USBL-capable acoustic modem. Contrary to the standard version, the modem of the seabed transponder has an additional integrated releaser mechanism at its bottom, which can be triggered acoustically to drop the anchor weight at the end of the mission. In addition, the transponder has a pressure sensor which can be used to calculate the water depth during operation. A cage, located at the top end of the seabed transponder and enclosing the modem transducer, mainly serves as protection but can also be used to deploy the transponder by crane.

To operate the transponder as communication relay and to support the localization of the AUVs, the EvoLogics transponders are additionally equipped with an internal development computer, which is the basis for the control software developed at GEOMAR. In order to save energy during the mission and thus extend the duration of the deployment, both transponders are also equipped with a so-called wake-up module, which is able to switch off both the modem and the internal computer if no acoustic communication is detected for a certain time. An incoming acoustic signal during its sleep phase causes the wake-up module to boot up the development computer and initiates a software restart.

The most important properties of the EvoLogics S2C R 18/34 seabed transponders are listed below.

Technical specifications of the S2C R 18/34 seabed transponders

Operating frequencies:		18 / 34 kHz
Transducer beam pattern:		Omnidirectional
Max. data transfer rate:		13.9 kbit/s
Operating depth:		1000 meters
Operating range:		3500 meters
Power supply:		5 Ah NiMH
Power consumption:	Standby mode	2.5 mW
	Listen mode	5 – 285 mW
	Receive mode	0.8 W
	Transmit mode	Up to 70 W

Weight (dry / wet):	Approx. 6 kg / 2 kg	
Dimensions:	Ø 448 mm x 850 mm	© Image: Evologics GmbH
Additional features:	Pressure sensor, wake-up module, internal development computer, acoustic releaser	

Underwater network integration of the transponders

As an integral part of the future underwater network at GEOMAR, the transponders will extend the possibilities for communication and localization of underwater vehicles in the network. Figure 5.5.1 shows schematically the operation in conjunction with the research vessel ALKOR and a Girona500 AUV. The transponders can be assigned to the following three main work tasks:

1. Communication relay: Due to the underwater topology, e.g. different water layers, a direct acoustic communication between different devices in the underwater network might be insufficient or even impossible. In this case, the transponder can serve as a communication relay that forwards data packets between the individual participants of the network.
2. Positioning support: Due to the known position of the transponder, distance measurements from an underwater vehicle to the transponder can be used to optimize the vehicle‘s positioning. For this purpose, the transit time of acoustic signals between the underwater vehicle and the transponder is measured. This information can then be fed into the vehicle‘s navigation system. The position of the transponder can be determined by USBL measurements from the ship.
3. Reference point with option for interaction: The known location of the transponder can be a starting point for an interaction with an underwater vehicle. For example, a plate with color patterns attached to the transponder could be used for an automatic camera calibration of the AUV‘s camera while the AUV is hovering in front of the transponder.

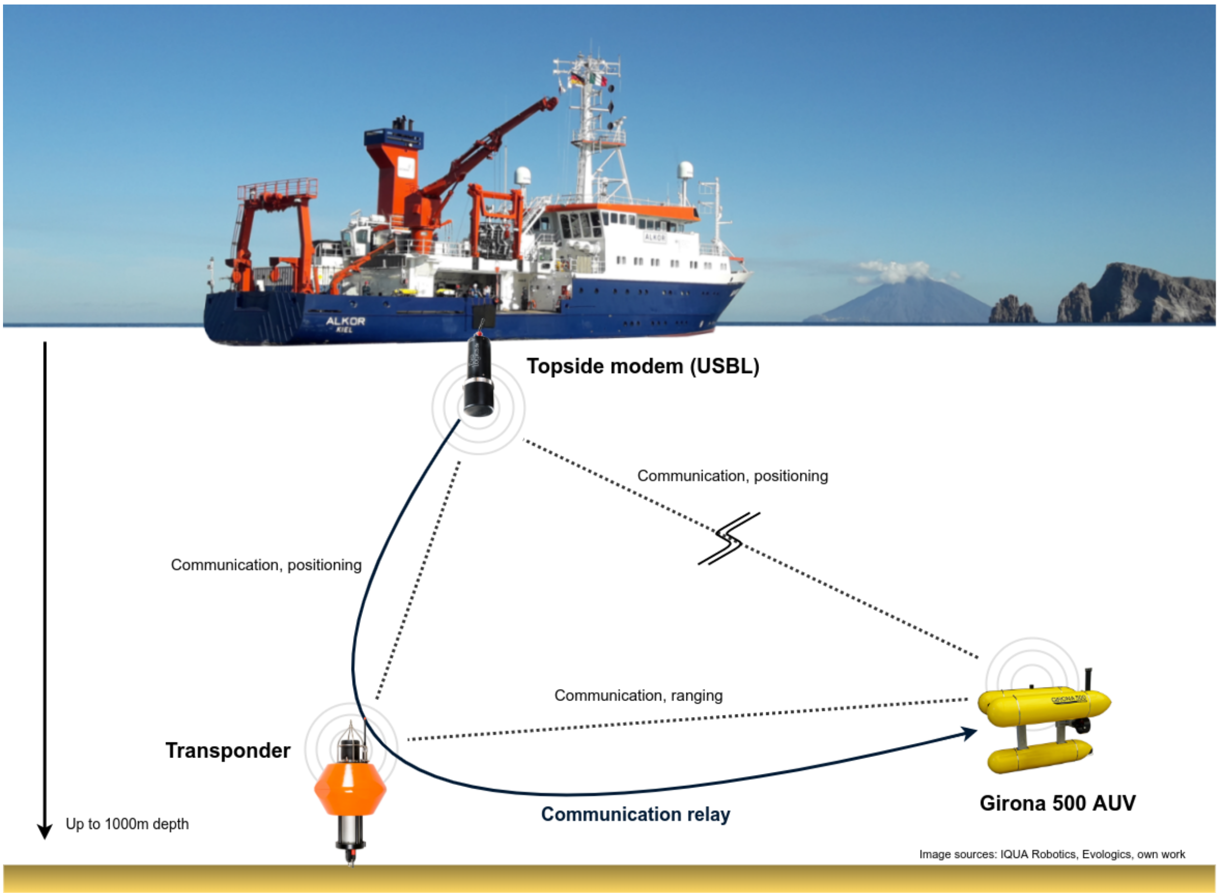

Fig. 5.5.1 Simplified underwater communication network

<u>Work performed during AL533</u>

During the first days of the cruise, various function tests were carried out to put the transponders into operation. For example:

- Switching the transponders on and off with and without wake-up module
- Status query and test of the releaser mechanism
- Set up and configuration of the internal development computer
- Query of the pressure sensors
- Communication tests with the ship's topside modem
- Distance measurement between topside modem and transponder

After these tests, the development of the control software for the transponders was started, of which a first prototype was completed during AL533. The software was installed on the internal computer of the transponders and registered in the system for automatic start-up during boot. Special attention had to be paid to the flawless operation in combination with the wake-up module, as the current device status of the transponder must be detected and restored even after a sleep phase. In addition, it had to be ensured that the software could also handle a "hard" shutdown of the computer by the wake-up module. For this purpose, a comprehensive logging module was implemented, which allows every action and decision of the software to be traced in detail. The logs created by the module can be used to track down software and hardware problems, especially in the event of failure. Overall, the software structure can be divided into two processes:

1. The main process of the software monitors the current operating status of the transponder. In addition to monitoring the battery voltage, this includes assigning the current status to one of the four basic statuses: "On deck", "descending", "on seafloor" and "ascending". The current device status controls the frequencies of status updates, configures and sets up the wake-up module and calculates the vertical speed when descending or ascending. The assignment to the four basic states is done based on depth measurements by the pressure sensor.
2. The communication process manages and controls the interaction of the software with the acoustic modem of the transponder. In addition to the initialization and configuration of the modem, incoming messages are decoded and answered based on rules. The communication in the underwater network is done using the Dynamic Compact Control Language (DCCL), which required an implementation of the corresponding DCCL software library.

Since the integration of the pressure sensor and releaser mechanism into the internal computer that has not yet been fully completed by the manufacturer, certain software parts were not yet fully operational during the time of the cruise. However, all relevant parts have already been implemented and prepared for later integration.

Final test deployment

After all components of both transponders had been checked and a first version of the software had been completed, a final functional test was carried out in the night from 13 to 14 February. In addition to a generic communication test, the aim of this test was to determine the accuracy of the USBL positioning.

For this purpose, one of the transponders was deployed in the Baia de Levante off Vulcano island at approx. 200 meters water depth (N 38° 24.7757', E 014° 58.5604') and continuously localized overnight by the ship's modem using its USBL function. For most of the entire deployment period (13.02.2020, 16:43 UTC – 14.02.2020, 09:30 UTC), the vessel was kept close to the drop position of the transponder. Just before RV ALKOR left the working area off Vulcano to head towards its final station, the transponder’s anchor weight was released acoustically and the transponder was recovered by ALKOR’s work boat without any problems.

The point cloud resulting from the USBL localization pings is shown in Figure 5.5.2. As can be seen in this figure, the accuracy of about 10 meters, usually assumed for USBL localization, was significantly exceeded: The diameter of the point cloud can be estimated to be about 45 meters. However, due to the regular patterns in the distribution of the pings and the fact that the ship stayed in the range of reliable acoustic communication with the transponder most of the time, the inaccuracy could be associated with inaccurate measurements of the lever arms during the setup of the localization software. Due to the faulty distances between the ship's GPS antenna and the ship's modem, minimal angle errors during positioning led to large deviations at a depth of 200 meters. This can be corrected by calibration of the system in advance to the deployment or also afterwards by a back-calculation using the ship's track. Since the test was primarily intended to confirm the general functionality and performance of the transponder, this step was omitted for time reasons. A data exchange with the newly developed transponder software was not yet possible during the test deployment due to a software error. However, the problem was identified and solved after the transponder was recovered. The overall quality of the acoustic communication with the transponder was excellent and supports the intended use of the transponders as a communication relay between ship and AUVs.

Fig. 5.5.2 USBL point cloud of transponder deployment

5.6 Multibeam Echo Sounder Imagenex 837B Delta T

(T. Weiß)

The Imagenex 837B Delta T is a small-sized multibeam echosounder (MBES). It works at a frequency of 260 kHz and has a transducer beam width of 120° x 3°. It uses 120 beams. The maximum range is 100 m, the minimum range is 5m. It can be used for profiling the ocean floor and for water column imaging. The data are recorded by the custom Delta T software (DeltaT.exe) in raw format (.837) installed e.g. on a laptop. The MBES was mounted on the submersible JAGO on its front lamp bar (Figure 5.6.1) during dive 1427 (Station 006). The primary goal was to test the multibeam's capabilities as a forward-looking sonar in comparison to the currently installed fish finder. The secondary goal of the mission was to create a test data set for the quantification of gas bubbles rising through the water column.

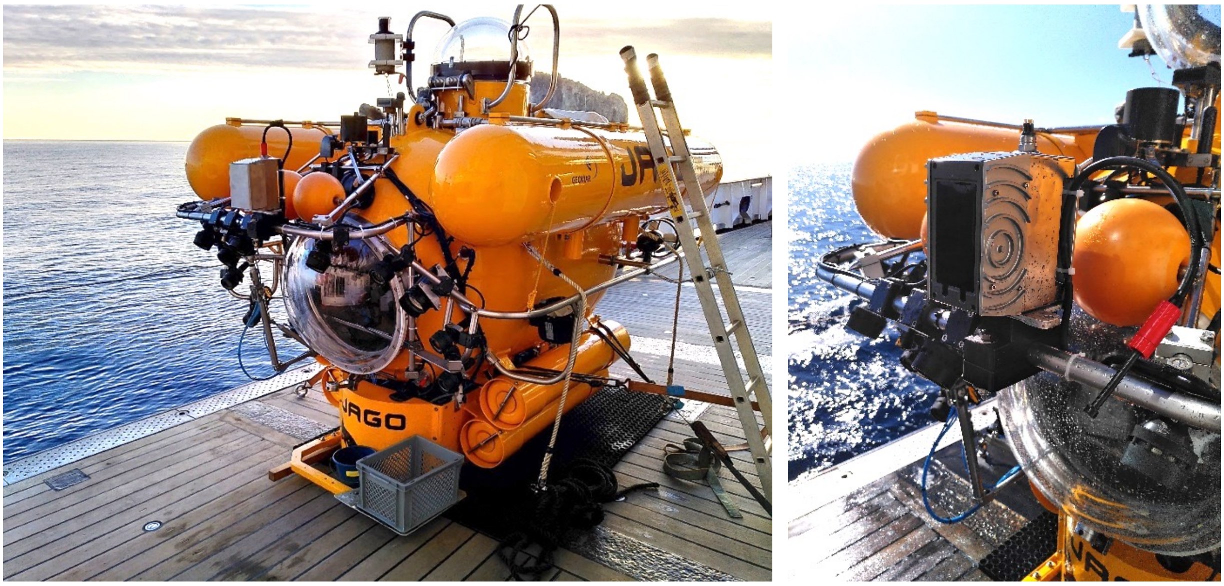

Fig. 5.6.1 Multibeam echosounder Imagenex Delta T on the lamp bar of submersible JAGO

The test site was located east of Panarea centered around 38° 38.63’N and 15° 5.14’E in 50m water depth (Figure 5.6.2). It was chosen because of known CO_2 seepages (Schmidt et al. 2015). Hence, the site offered the chance to train also the detection of bubble streams with acoustic methods. To locate active bubble streams, the video-like images provided by the multibeam were observed on the laptop inside the submersible and the submersible was respectively navigated until active seeps were visibly confirmed. Since the site was located in a trench-like formation, the multibeam could also be tested as an additional source for navigating the submersible. The MBES could clearly identify the slopes on the southern and northern boundaries of the trench. In Figure 5.6.2 (top) the USBL position of JAGO at UTM time 09.02.2020 07:49 is indicated as a yellow dot. Figure 5.6.2 (bottom) shows a screenshot of the Delta T software at the same time point. The slope on the left side is clearly visible in the perspective view of the MBES.

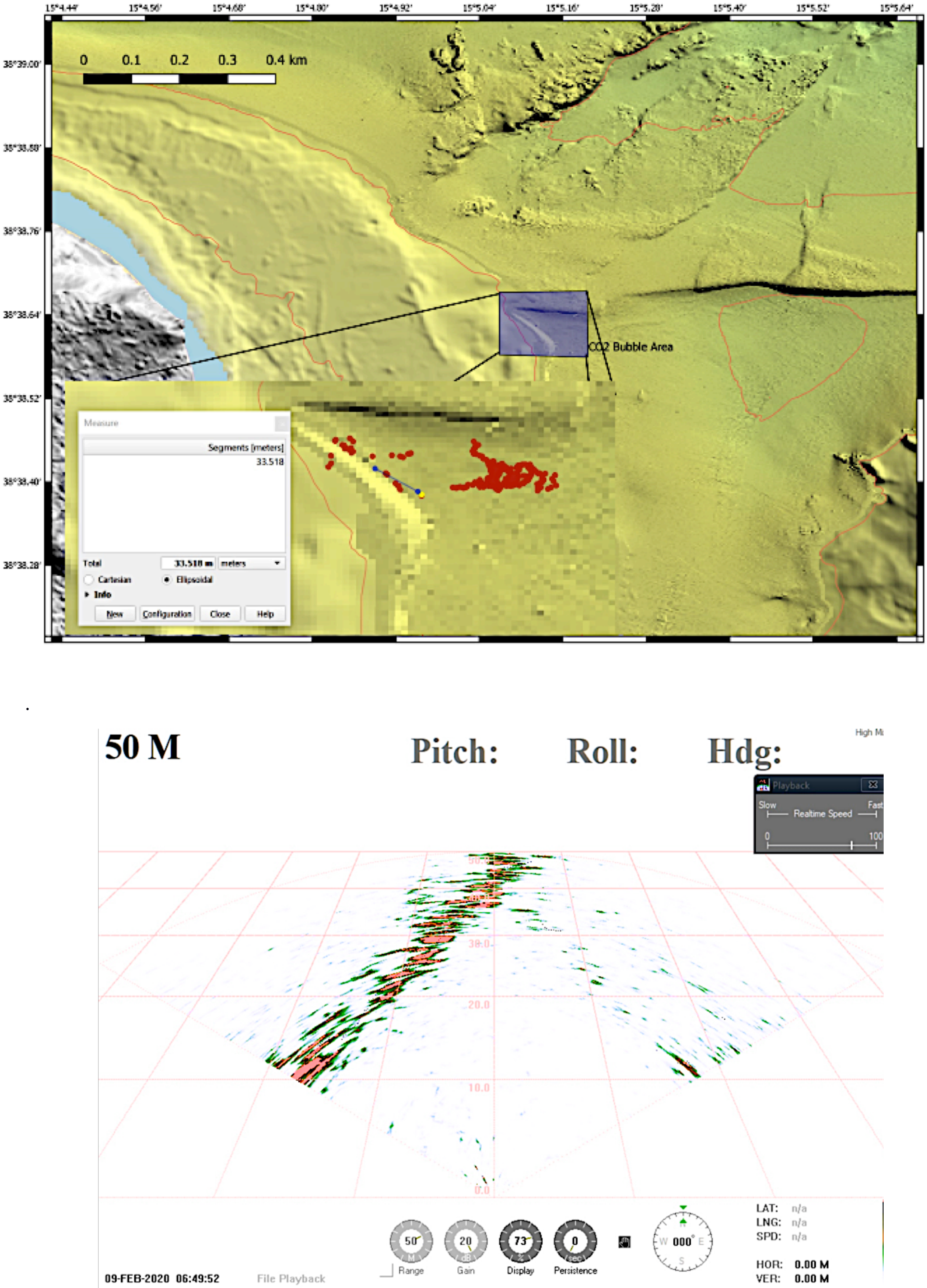

Fig. 5.6.2 Panarea bubble area. Top: The red dots indicate the USBL track of JAGO, the yellow dot is the position at UTC time 07:49. Bottom: Perspective view of the Imagenex multibeam at UTM time 07:49

For gaining a better overview of the surrounding, acoustic sensors are an important source of additional information for the pilot and the observer. This could play even a bigger role if turbidity conditions are worse and surrounding structures are more complex. The currently installed transducer of the fish finder sonar Garmin 320C 200kHz uses only one beam with an opening angle of 20°. In this case the submersible needs to be moved clockwise or counter-clockwise to get an acoustic overview. The wide opening angle of 120 degrees of the Imagenex MBES transducer gives immediately a better overview without the necessity of turning the whole submersible.

Besides the evaluation of navigational support, the multibeam was used to create a test data set for gas bubble quantification. The Imagenex Delta T used here is usually installed on the Gas Quant II lander system of GEOMAR. This autonomous lander was built to quantify bubble streams over a longer period of time by detecting rising gas bubbles passing the horizontally directed beam swath. The settings of the system are programmed in advanced and cannot be changed during a deployment.

The installation of the multibeam on the submersible offered the chance to create test data sets with different range and attenuation settings at the same spot. This data set is a valuable source of information to select optimal settings for future deployments of the Gas Quant II lander. 16 scenarios were tested and each created a test file with a duration of ca. two minutes.

5.7 Collection of still-, video- and 360°-footages for public outreach work

(T. Kwasnitschka, J. Kilmmeck, N. Linke, K. Hissmann)

An important concern of GEOMAR is to share its activities and the outcome of its scientific work with the public. Also research cruises are used to gather material for the public outreach work of the research centre. AL533 was therefore accompanied by a photographer and a cameraman to document all aspects of the work on board.

The freelance photographer Nikolas Linke and the cruise leader produced digital photos and short video clips. Nikolas Linke used a Sony a7III (4K, 30 fps) and a Sony a6000 (1080p, 50fps) camera. He shot more than 1.100 digital photos (3,24 GB), edited and annotated them with keywords and made 323 video clips (261 GB). The images were forwarded to the communication and media department of GEOMAR for different public outreach purposes.

Furthermore, GEOMAR currently expands its media presence by employing immersive filmmaking techniques. One of the goals of the AL533 media coverage was to create footage for the production of a fulldome video documentary to be distributed among science museums and digital planetariums. A second creation will be an online short documentary in spherical video format, to be viewed using 360° video browsers or head mounted displays. The creation of such footage was the prime task of Jens Klimmeck, who joined the cruise as cameraman. He used an INSTA 360 PRO II camera as well as two INSTA One 360° video cameras, the latter along with shallow underwater and aerial drone deployments. The footage is currently in post-production and screening at GEOMAR's ARENA2 visualization lab, which also features a digital projection dome. A first rough cut has been submitted to the 2020 Jena Fulldome Festival.

The cruise leader drafted a new consent form, in which individuals give permission for the usage of any images in which they appear for media and public outreach purposes.

5.8 Geological surveys and samples

(D. Casalbore, K. Hissmann)

The main aim of the dives with the submersible JAGO was pilot training and testing of support equipment (USBL etc). Since the collection of samples was also part of the training, and the cruise took place at locations that are of high scientific interest of the volcanologists at the University Sapienza of Rome, a total of 21 volcanic rock samples were collected at different sites. The samples were taken by Dr. Danile Casalbore to Rome for further scientific.

Station No.	Date	Time	JAGO Dive No.	Sampling site		Water Depth	Location / Remarks
				Latitude	Longitude		
ALKOR	2020	(UTC)		(°N)	(°E)	(m)	
AL533_8-2	9.2.	13:52	1428 / 3	38°48.19’	15°12.15’	100	Stromboli, Sciara del Fuoco. 12 samples of volcanidastic material
AL533_9-2	10.2.	10:13	1429 / 4	38°24.71’	14°58.70’	204	Vulcano, La Fossa Caldera, Punta Roia lava flow = 4 rock samples. Punta Luccia = 1 rock sample
AL533_13-2	12.2.	16:11	1430 / 5	38°24.75’	14°58.50’	145	Vulcano, La Fossa Caldera, Punte Nere lava flows = 2 rock samples.
AL533_15-2	13.2.	12:08	1431 / 6	38°26.45’	14°58.12’	288	Pillow lava field between Vulcanello and Lipari. 2 rock samples

6 Station List AL533

6.1 Overall Station List

Station No.	Date	Time	Gear	Gear Dive No.	Latitude	Longitude	Water Depth	Remarks
ALKOR	2020	(UTC)			(°N)	(°E)	(m)	
AL533_1-1	7.2.	11:29	Boat	1	38°24.76’	14°58.55	198	Work boat test + handling test for JAGO
AL533_2-1	7.2.	11:49	JAGO	Surface only	38°24.76’	14°58.57	204	Handling test for JAGO, no submerging
AL533_3-1	7.2.	13:02	AUV		38°24.77’	14°58.56’	203	Buoyancy test AUV
AL533_4-1	8.2.	07:07	Boat	2				Boat deployed for JAGO
AL533_4-2	8.2.	07:19	JAGO	1426 / 1	38°24.66’	14°58.59’	161	Video survey lava flow off Vulcano
AL533_5-1	8.2.	12:20	AUV	Anton 85-87	38°37.99’	15°05.50’	42	ANTON Tripple camera mission
AL533_6-1	9.2.	15:13	Boat	3	28°38.65’	15°05.13’	42	Boat deployed for JAGO
AL533_6-2	9.2.	07:21	JAGO	1427 / 2	38°38.64’	15°05.13’	43	CO2 gas seeps site off Panarea, multibeam test for gas bubble detection + video survey
AL533_7-1	9.2.	10:34	AUV	Luise 09	38°37.69	15°07.10’	73	LUISE Acoustic test
AL533_8-1	9.2.	12:34	Boat	4	38°48.20’	15°11.77’	253	Boat deployed for JAGO
AL533_8-2	9.2.	12:48	JAGO	1428 / 3	38°48.17’	15°11.90’	182	Video + sampling survey Stromboli along 100 m contour line
AL533_9-1	10.2.	07:03	Boat	5	38°24.71’	14°58.58’	176	Boat deployed for JAGO
AL533_9-2	10.2.	07:27	JAGO	1429 / 4	38°24.71’	14°58.68’	185	Photo + video survey dive off Vulcano
AL533_10-1	10.2.	12:34	AUV	Anton 88	38°24.78’	14°58.62’	214	ANTON Acoustic tect
AL533_11-1	12.2.	09:14	AUV	Anton 89	38°24.76’	14°58.72’	150	ANTON Water column test
AL533_12-1	12.2.	12:06	AUV	Anton 89	38°24.81’	14°58.59’	221	ANTON Water column

								test
AL533_13-1	12.2.	13:48	Boat	6	38°24.81'	14°58.50'	204	Boat deployed for JAGO
AL533_13-2	12.2.	13:57	JAGO	1430 / 5	38°24.78'	14°58.50'	192	Test dive for rim thrusters off Vulcano
AL533_14-1	13.2.	07:08	Boat	7	38°24.78'	14°58.62'	210	Boat deployed for JAGO
AL533_14-2	13.2.	07:24	JAGO	Surface only	38°24.79'	14°58.61'	218	Foto / video shooting session with vehicles at water surface
AL533_14-3	13.2.	07:41	AUV	Anton 90	38°24.80'	14°58.59'	225	ANTON Deep dive
AL533_15-1	13.2.	11:56	Boat	8	38°26.49'	14°58.13'	278	Boat deployed for JAGO
AL533_15-2	13.2.	12:08	JAGO	1431 / 6	38°26.48'	14°58.06'	202	Video + sampling dive at pillow lava mounds off Lipari
AL533_16-1	13.2.	16:43	Transp.	Emil 1	38°24.78'	14°58.57'	214	Transponder EMIL deployment + mooring
AL533_16-2	14.2.	05:22	AUV	Anton 91	38°24.76'	14°58.49'	175	ANTON Photo survey with CoraMo camera
AL533_17-1	15.2.	07:04	AUV	Anton 92	38°29.90'	14°57.92'	104	ANTON dive aborted
AL533_18-1	15.2.	11:06	Boat		38°37.46'	15°04.68'	44	Boat deployed for JAGO
AL533_18-2	15.2.	11:19	JAGO	1432 / 7	38°37.45'	15°04.70'	45	Mutual dive with AUV, rescue buoy test off Panarea
AL533_18-3	15.2.	11:31	AUV	Anton 93-94	38°37.40'	15°04.67'	52	ANTON mutual dive with JAGO

Explanations: JAGO = Manned submersible „JAGO“, ANTON / LUISE = AUVs, EMIL = USBL seabed transponder

The electronic version of the list and additional cruise data are also permanently available via the GEOMAR OSIS data portal under the link: https://portal.geomar.de/metadata/leg/show/354225

7 Data and Sample Storage and Availability

All cruise meta-data – including output of the onboard DSHIP-System - have been entered in the GEOMAR Ocean Science Information System (OSIS), managed by the Kiel Data Management Team (KDMT), and intended for permanent archiving of such data. The data are freely available via the link: https://portal.geomar.de/metadata/leg/show/354225 (keyword AL533).

All video data obtained during JAGO dives have been stored in the video archive of the GEOMAR JAGO-team. The videos of the bottom surveys that were of interest for the geologists in Rome were copied on a hard drive and forwarded to Dr. Daniele Casalbore. He also took the rock samples to Rome.

8 Acknowledgements

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10 Appendices

10.1 Selected Pictures of Shipboard Operations

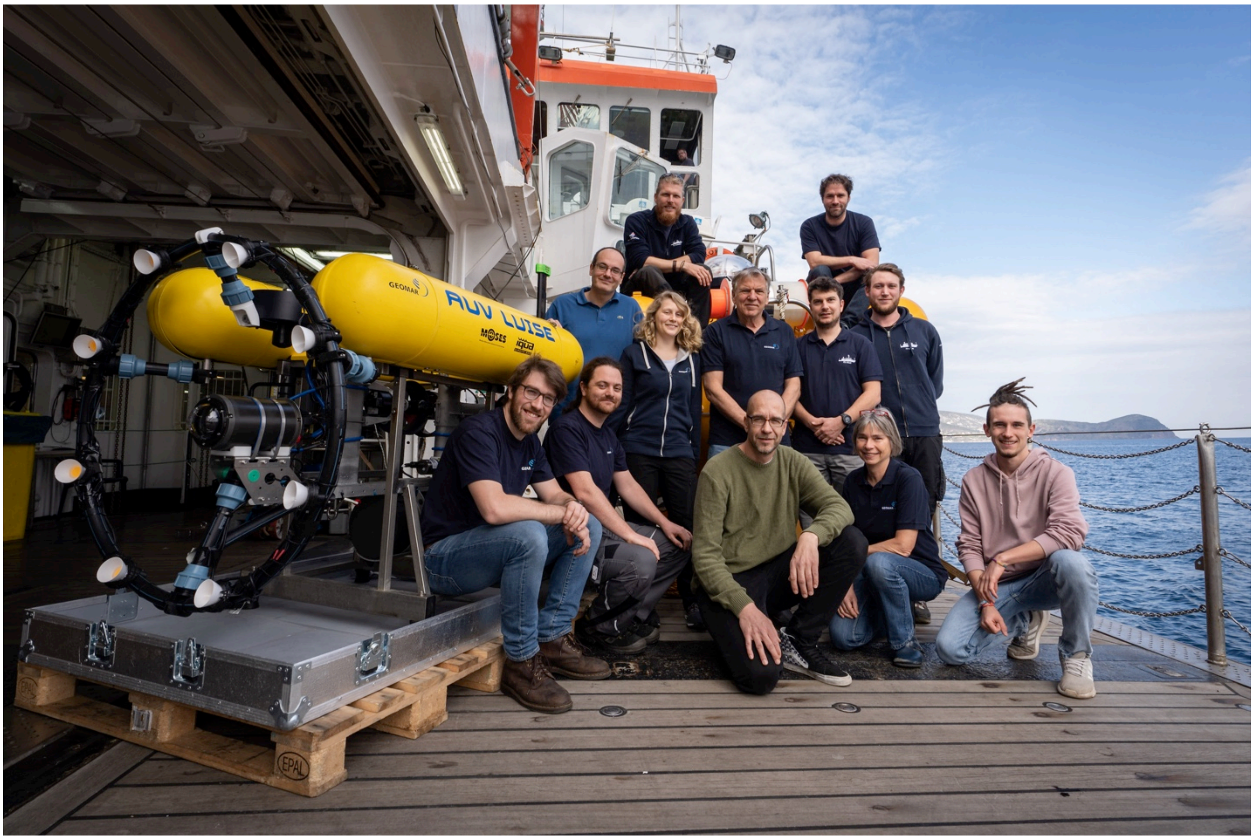

Fig. 10.1.1 The cruise participants of AL533 with AUV LUISE and submersible JAGO on board RV ALKOR off the Aeolian islands. From left, sitting: Emanuel Wenzlaff, Nikolaj Diller, Jens Klimmeck, Karen Hissmann, Nikolas Linke; from left, standing: Daniele Casalbore, Sylvia Reißmann, Jürgen Schauer, Patrick Leibold, Hendrik Hampe; from left, on top of JAGO: Peter Striewski, Tim Weiß. Photo: Nikolas Linke

Fig. 10.1.2 Submersible JAGO off the northeast flank of Stromboli volcano. Photo: Karen Hissmann

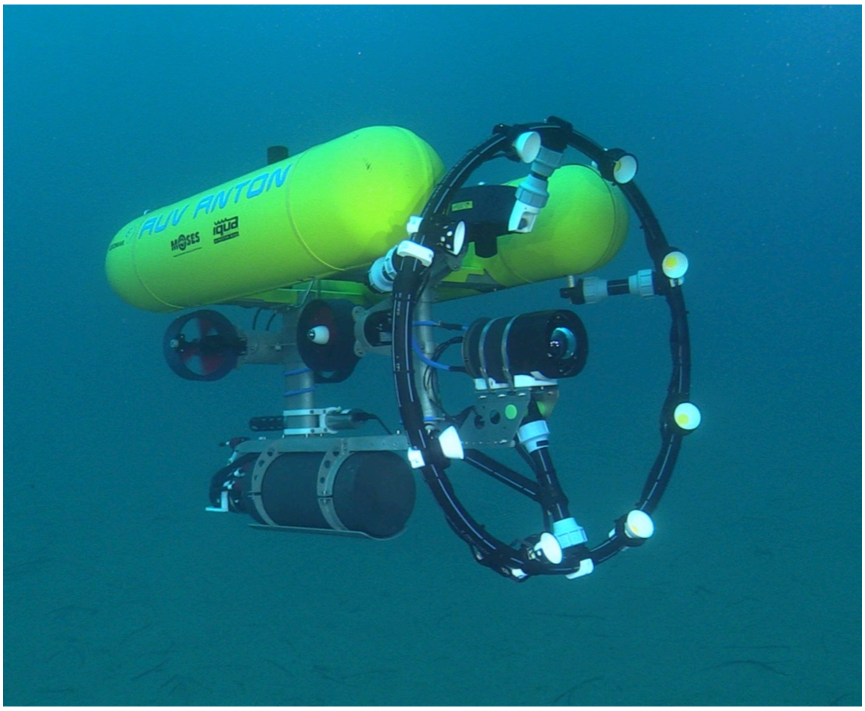

Fig. 10.1.3 AUV ANTON, photographed from on board submersible JAGO during a mutual dive off Panarea Island. Photo: Jürgen Schauer

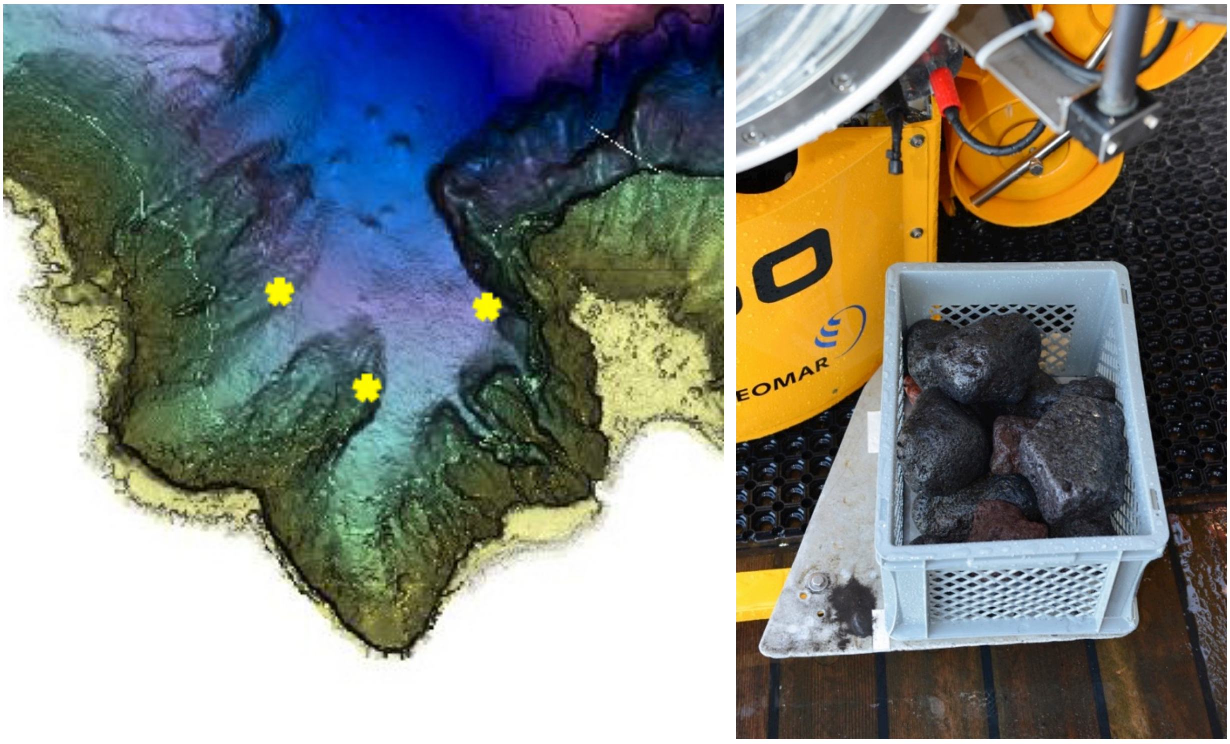

Fig. 10.1.4 Multibeam image of the working area in the Baia de Levante with rock sampling sites (left, image Daniele Casalbone) and JAGO’s sampling basket (Photo: Karen Hissmann)

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